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FOREWORD

AUGUST 19, 1952.

ATOMIC ENERGY COMMISSION,
1901 Constitution Avenue, Washington, D. C.
(Attention: Mr. Gordon Dean, Chairman.)

GENTLEMEN: As you know, the Joint Committee, on October 19 of last year, reported to the Congress in part as follows:

> "The Committee is keenly interested in the current study program involving eight private industrial firms. These are exploring the possibility of offering to build reactors wholly or partly at their own expense, with the dual purpose of producing power for sale to the public and plutonium for sale to the government. It is recommended that the complex factors entering into such a possibility be brought rapidly to a point of crystallization, so that they may be properly evaluated and judged."

The purpose of this letter is, first, to advise that I shall recommend to the Joint Committee that it hold a series of meetings on "industrial participation" early during the next session of Congress; and, second, to request a written statement of the Commission's policy views in this area as soon as feasible.

Thank you for your cooperation.

Sincerely yours,

/s/ CARL T. DURHAM,
Chairman.

UNITED STATES

ATOMIC ENERGY COMMISSION

Washington 25, D. C.

SEPTEMBER 4, 1952.

Honorable CARL T. DURHAM,
Chairman, Joint Committee on Atomic Energy,
House of Representatives.

DEAR MR. DURHAM: This will acknowledge receipt of your letter of August 19th advising the Atomic Energy Commission that you intend to recommend to the Joint Committee that it hold a series of meetings on "industrial participation" early during the next session of Congress, and requesting a written statement of the Commission's policy views in this area as soon as feasible.

The problems of the Industrial Participation Program are being studied in a series of Commission meetings now under way, and Commission policy in this field should be crystallized to the point where

profitable discussions with the Joint Committee are possible by the first of the year. We would suggest that our policy report to the Committee be made at that time.

Sincerely yours,

UNITED STATES ATOMIC ENERGY COMMISSION
GORDON DEAN, *Chairman.*

The following material bearing upon atomic power problems was compiled by the Committee staff at the request of the Chairman for the use of the Joint Committee on Atomic Energy. All statements have been meticulously screened so as to include unclassified and publishable information only.

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Part I

A. SOME POINTS OF DEPARTURE

1. Today the United States Has in Operation or Under Construction More Than Twenty Large and Small Atomic Reactors

The reactors at Hanford, Washington, produce plutonium, material which can be used in a weapon; and they also produce quantities of heat which is removed and dissipated. Heat such as this might be harnessed to create power for the generation of electricity.

As more reactors of different kinds are built, more becomes known about possibilities of deriving useful commercial power. The United States now possesses or is constructing reactors as follows:

(*a*) Hanford, Washington: Three war-built production reactors, plus post-war production reactors, plus a small war-built research reactor;
(*b*) Savannah River, South Carolina: Production reactors;
(*c*) Arco, Idaho: Two sizeable new research reactors and a land-based prototype of a submarine reactor;
(*d*) Argonne National Laboratory, Illinois: Three small research reactors;
(*e*) Schenectady, New York: Land-based prototype for an improved submarine reactor;
(*f*) Los Alamos, New Mexico: Two small research reactors;
(*g*) Oak Ridge, Tennessee: One war-built pilot-model reactor, plus three small reactor "experiments";
(*h*) Brookhaven, New York: One research reactor;
(*i*) North Carolina State University: One small research reactor.

2. Atomic Power Will Propel an American Submarine by 1954 and Possibly an American Aircraft Carrier by 1957

In June, 1952 the President laid the keel for the first atomic-powered submarine; and this vessel will be afloat in 1954. The Assistant Secretary of the Navy for Air has announced that "it is reasonable to believe we should have our first atomic-powered carrier in about five years."

From a technical standpoint atomic power for driving ships is closely related to atomic power for generating electricity.

"The Nautilus will be able to move under the water at a speed of more than twenty knots. A few pounds of uranium will give her ample fuel to travel thousands of miles at top speed. She will be able to stay under water indefinitely. Her atomic engine will permit her to be completely free of the earth's atmosphere. She will not even require a breathing tube to the surface.

"The military significance of this vessel is tremendous. The engine of the Nautilus will have as revolutionary an effect on the navies of the world as did the first ocean-going steamship 120 years ago.

"But the peaceful significance of the Nautilus is even more breath-taking. When this ship has been built and operated, controllable atomic power will have been demonstrated on a substantial scale."—from an address by President Harry S. Truman at the keel-laying of the first atomic submarine, Groton, Connecticut, June 14, 1952.

3. A Major Effort Is Being Made To Build an Atomic-Powered Military Airplane

The Chairman of the Atomic Energy Commission stated in 1951, "I think in the next decade you will probably have a plane in the air the power for which comes from a reactor." Achieving nuclear-propelled flight is a far harder technical task than achieving large quantities of electricity from nuclear power.

"My belief is that our efforts to fly an aircraft on nuclear power will be successful. The difficulty of the task and the value of the result combine to form a challenge which is in my opinion unmatched."—from remarks of M. C. Leverett, Aircraft Nuclear Propulsion Project, General Electric Company, Oak Ridge, Tennessee.

"The impetus given to the reactor program by military requirements will result in an earlier development of power for industrial purposes than could otherwise have been the case. This situation is not new in the world of technical development; a well-known example is the railway Diesel locomotive, whose development was sparked by the naval requirement for a submarine Diesel engine."—from remarks of Brig. Gen. James McCormack, Jr., Director, Division of Military Application, Atomic Energy Commission, before the Teachers In-Service Training Course, New York, N. Y., March 31, 1949.

4. The Army Has Under Way an Atomic Power Program

The Secretary of the Army recently announced that electricity from atomic power (possibly for remote bases, port facilities, and catastrophe areas) is being studied.

"I think in a decade from now, and certainly in less than two decades, it may be possible to apply nuclear energy to certain specific highly critical problems of energy generation. Whether this will be to establish a station near the North Pole, or to propel ships or rockets, I don't know; but it will be a case where cost is not important, where one is willing to divert quite valuable material to a specialized and important objective."—from statement by Dr. J. Robert Oppenheimer, Chairman of the General Advisory Committee to the Atomic Energy Commission, before a United Nations committee on international control of atomic energy, April 29, 1947.

5. There Is Today No Question That Atomic Power for Industrial Purposes Is Technically Feasible, if Cost Were To Be Disregarded

All authorities are now agreed that large-scale generation of electricity from atomic power (leaving aside cost) is possible. Token amounts of electricity were actually produced through a reactor at Arco, Idaho in December, 1951. A few weeks earlier the British had used a reactor to heat buildings at Harwell, England.

"This whole question of power reactors is largely one of economics. I think practically everyone associated with the reactor phase of our program agrees that the technology has reached the point where reactors can be built to produce power. As a matter of fact, you may recall that last December one of our reactors out in Idaho actually produced some power experimentally. That reactor isn't a real power plant by any means, but the experiment proved beyond any doubt that power can be produced from atomic power. But if we hadn't believed this all along we never would have begun work on the two submarine reactors we are now developing."—from remarks of Gordon Dean, Chairman, U. S. Atomic Energy Commission, before the Economic Group, Detroit, Michigan, March 3, 1952.

6. The Great Question Concerns the Cost of Electricity From Atomic Energy

Many authorities tend to believe that atomic power can compete today with conventional power in areas where the cost of ordinary fuels is high. It is assumed that in most areas of the United States, however, atomic power would be more expensive than conventional power over the next few years. Beyond this time atomic power may or may not become commercially competitive—the authorities are divided in their forecast.

"If nuclear plants for the propulsion of a submarine are feasible, why is it not possible to use the same kind of plant for the generation of central station power? There is no reason except the matter of economics. It simply is not possible in the present state of technology to design and construct nuclear reactors that would produce a unit of electric energy for commercial purposes at anywhere near the same cost as conventional fuels."—from remarks of Philip Sporn, President, American Gas and Electric Company, before National Industrial Conference Board, New York City, New York, October 17, 1952.

"The cost of construction of a nuclear power plant is still essentially unknown. We have never even designed, much less built and operated, a reactor intended to deliver significant amounts of power economically."—from an article by Dr. Lawrence R. Hafstad, Director, Division of Reactor Development, Atomic Energy Commission, in Scientific American for April, 1951.

"Study of the development of atomic energy from 1942 leads me to feel that the strides the engineers and scientists are making are so great that 'power only' reactors may be nearer than we dare hope for, even though we are still in the early phases of research and development."—from an address by Commissioner Eugene M. Zuckert, Atomic Energy Commission, before the American Chemical Society, Chicago, Illinois, September 11, 1952.

"We are convinced, even with our present incomplete knowledge of this technology, that fission of natural uranium will produce energy that can and will compete economically with coal or oil. We are thinking at this stage of quite large central power stations."—from statement of J. Lorne Gray, General Manager, Atomic Energy of Canada, Ltd., before the Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

7. A Single Reactor Can Be Designed To Produce Both Plutonium and Power; Hence the Price of Power Might Be Reduced by Selling It as a Co-Product With Plutonium

A Hanford-type reactor produces plutonium but no power. A reactor can be designed to produce only power. It is also feasible to design a reactor which produces both. These three alternatives are often described as follows: Plutonium-only reactors; power-only reactors; and dual purpose reactors.

In a dual purpose reactor part of the cost might be charged against the plutonium output—plutonium being scarce and valuable. Power might then be offered to consumers at lower prices.

"There is one clear break that atomic power development work will get because of the international situation. This stems from the high value placed on plutonium because of its usefulness in weapons. Since reactors can be made to produce both power and plutonium at the same time, this means that the income received from producing plutonium can be used to reduce the cost—and therefore the price—of the power * * *.

"Although the day of economical power from fission is not right around the corner, there are some way stations along the road that it will be very

encouraging to arrive at. One we have already reached. This was the experimental production of power in Idaho. The next will be the successful operation of a submarine reactor, where cost is not a controlling factor but where the power will be used for a practical purpose. Possibly the next will be the day that power is produced at competitive prices with the aid of the weapons market for plutonium."—from an address by Gordon Dean, Chairman, Atomic Energy Commission, before the Chamber of Commerce, San Diego, California, March 19, 1952.

8. Opinion Is Divided on Whether the United States Has Been Carrying Out a Satisfactory Atomic Power Program

The progress of reactor development in relation to atomic power has evoked many differing expressions of opinion. The following are illustrative:

"I myself feel that there has been a lack of enthusiasm for the development of useful atomic power."—Dr. Harold Urey, University of Chicago Round Table, November 25, 1951.

"After the successful operation of the Hanford reactors, the additional task to build a power reactor was certainly no more difficult than had been the original wartime assignment. Yet it was over 6 years later when the reactor at Idaho first produced [token amounts of power] last December.

"The slowness did not arise from a lack of designs for power reactors which reputable scientists and engineers were willing to build and test. It came rather from an unwillingness of the Commission to proceed with any one of these designs until all of the advisers agreed that this was the best design.

"The situation might be likened to an automobile equipped with separate brake levers for each passenger. At every road junction the driver not only had to discuss his preference of route with his riders, but he had to wait until all were convinced, because any one could stop the car. Considering that the power reactor territory is not clearly mapped, it is not surprising that more time was spent stationary than moving. We need either to remove some of the extra brakes or to shift riders to men who will reply to the driver, 'Take the road that you think best and let's move ahead.' "—from remarks of Dr. Kenneth S. Pitzer, Dean of Chemistry, University of California, Berkeley, California, March 7, 1952.

"The process of 'learning by building,' which resulted in such astonishing development in the automobile and airplane industries, might well have had advantages over a philosophy of cautiously testing parts and waiting for agreement among experts on how to build a prototype of the ultimate power reactor. In the absence of actual test data on an operating experimental power unit, no one could possibly speak with authority and public confidence has suffered in a vacillation between undue optimism and unestablished pessimism."—from statement of Dr. Farrington Daniels, Professor of Physical Chemistry, University of Wisconsin, in the November 1952 Bulletin of the Atomic Scientists.

"The Reactor Development Subcommittee, under the chairmanship of the Committee Vice-Chairman, Representative Durham, has long been active and has vigorously sought to communicate its sense of urgency to the technical people working in this field. Its work has helped concentrate the reactor program upon specific priority objectives, reducing the earlier tendency to study much but to undertake little which is concrete. As regards one vital reactor project, the Subcommittee concluded that a major policy decision has been too long delayed and that additional delay might seriously hamper progress. The Subcommittee therefore informed the appropriate civilian and military authorities that, unless the necessary decision were reached within a specific time period, they would be requested to appear and explain their reasons for deferring judgment. The decision (one which the Subcommittee itself endorsed) was made on the next-to-last day of the stipulated time period. . . .

"The Committee also renews its 1949 recommendation, particularly as regards thorium breeders and plutonium production reactors of the future, that 'reactor development * * * proceed with all possible speed.' "—from "Report of the Joint Committee on Atomic Energy to the Congress of the United States." October 19, 1951.

"When we recall that the neutron was discovered only 20 years ago, that 13 years ago we were just learning of the process of fission itself and the possibility of initiating a chain reaction, that intensive work on nuclear energy was started only 11 years ago, that the first nuclear reactor was triggered only 10 years ago, and that—following the magnificent achievements of the Manhattan Engineer District during World War II—the Atomic Energy Commission has been in business only 5 years, we realize how fast we are progressing and we gain confidence in the future * * *."—from an address by Dr. John W. Landis, Reactor Division, Atomic Energy Commission, before ASME, Washington, D. C., November 13, 1952.

A. If you ask me if the reactor development program has moved as rapidly as the Congress, the President, the Commission, the military, the General Manager of the Commission, or I want it to move, the answer is "no." You ask if it has been unduly slow. The answer is "no" to that, too. Though the program may be criticized for other things, I don't see how any program that builds up in three years from approximately $50 million per year to more than $100 million can be called slow.

Q. What are the factors which affect the speed of the program?

A. There are a great many factors which affect the speed of reactor development work. One is the necessary and proper very high priority which the Commission has put on the production of fissionable materials for weapons. Another is the time it took to provide the facilities we needed. A third is the consideration which must be given to factors of cost, safety, and efficient utilization of fissionable materials when measured against the actual results to be obtained from a given reactor development experiment. Remember, we are not talking about laboratory bench work. We are talking about experiments (research and development for new types of reactors and the first models) which may cost anywhere from five to fifty million dollars each.

In general, in response to a query as to whether the program for the development of atomic power has moved slowly, the answer obviously appears to be "yes," if you use as a yardstick the number of machines we have producing electric power. But if you take into account the fact that the United States is particularly blessed with reserves for cheap, conventional power, so that this was not one of our urgent objectives, and if you apply a yardstick of real scientific and engineering accomplishment and measure the filling of the reservoir of knowledge and experience on which the future development of power depends, then I say our program has moved at a constantly increasing rate. Certainly today it has considerable momentum.—from interview with Dr. L. R. Hafstad, Director of Reactor Development, A. E. C. in Chemical & Engineering News, September 15, 1952.

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B. INDUSTRY AND ATOMIC POWER: SOME RECENT HISTORY

April 14, 1950: Termination of the Only Major Industrial Power Project

From its earliest days the Atomic Energy Commission sponsored one major development project that had no direct military aspect and looked toward exploring possibilities of useful industrial power. This was the power-breeder reactor (IPBR) carried forward at the Knolls Atomic Power Laboratory, Schenectady, New York. When a decision had to be made whether or not actually to build this reactor, the Commission—due to the estimated cost and other more complex factors—decided against proceeding. A press release dated April 14, 1950 announced that the Knolls Laboratory would henceforth work upon an improved type of submarine reactor; and a prototype is today under construction near Schenectady. The earlier work upon a power-breeder reactor has materially contributed to progress on the submarine power plant. Since Spring, 1950, however, there has been no major project whose purpose is to achieve a reactor directly advancing industrial power.

"Q. At one time the Intermediate Power-Breeder Reactor was part of the reactor program. Among the reasons given by the AEC for this reactor was that the AEC hoped the reactor would lead to production of central station or industrial power in the 'distant' future. Yet work on this reactor was deferred in 1950 in favor of work on the Submarine Intermediate Reactor. What was the reason for that deferment?

"A. When we first started the Intermediate Power-Breeder Reactor project at Schenectady, we thought we could take a big jump and build a reactor operating on neutrons of intermediate energy levels and at the same time make it breed and produce power. General Electric carried the project far enough along to see that this was a big job to do all at once. In view of the Navy's established requirement for submarine propulsion systems and the darkening international situation, it was decided to make the first intermediate reactor one for submarine propulsion and not attempt in the same experiment to combine breeding with an effort at economical power.

"Q. How has this shift affected AEC's contribution to production of central station or industrial power?

"A. I doubt if it has affected the power picture much one way or another. What we must remember about the mobile military reactors is that they may make a very substantial contribution to future power reactors of any kind. Demonstration and use of high-cost power is a step toward lower cost power. The nuclear power plant for a large ship on which Westinghouse is beginning development work will more nearly resemble a central station installation than the submarine plants."—from interview with Dr. Lawrence R. Hafstad, Director, Division of Reactor Development, Atomic Energy Commission, in Chemical and Engineering News, September 15, 1952.

June 11, 1950: An Overture From Industry

Two months after termination of the only major industrial power project Dr. Charles Allen Thomas, President of the Monsanto Chemical Company, made a speech proposing a plan which "contemplates the

design, construction, and operation of an atomic power plant built by *industry* with its own *funds*, *producing power* and plutonium in the *same plant*." While Dr. Thomas had foreshadowed such a proposal as early as 1946, the activities that came to be known as "the industrial participation program" followed after his June 11, 1950 address. Here he said, in part:

> "The uranium, the necessary source of power, would be loaned or leased by the government to the industrial plant, which would convert a portion of it into plutonium and power. The power would belong to the industry that put up the money but the plutonium and the isotopes and all the fissionable by-products *at all times* would belong to the government. * * * Industry would receive a fee from the government for converting a portion of the uranium into plutonium. * * * Industry would get power at a price attractive enough to venture its investment and the government would get its plutonium at a price cheaper than it is now making it at Hanford. * * * We will have industry in there trying to cheapen costs, improve yields, designing low cost plants. Thus competitive progress is made."—from an address of Dr. Charles Allen Thomas, President, Monsanto Chemicals Company, at Hobart and William Smith Colleges, Geneva, New York, June 11, 1950.

January 28, 1951: Origin of the "Industrial Participation Program"

The Commission announced that it had received proposals from industrial groups "expressing willingness to bring their technical resources into the atomic energy program under somewhat different arrangements, in which a large share of initiative and responsibility would rest with the industrial group." The announcement went on to say that "the Commission has discussed these proposals with the men whose vision created them, and has suggested conditions under which it would be willing to go forward with the first step involved in each proposal—a study of its reactor development program by qualified technical groups from the industrial concerns involved." In addition,

> "The following general policy guided consideration of these proposals:
> "The Commission will undertake cooperative activities with industrial concerns or groups of concerns to explore possibilities for their participation—on their own initiative, using their own resources—in development of applications of atomic energy for power purposes in such manner and extent as to insure: (1) maximum attention to the atomic energy production program in all its phases; (2) special effort being placed on those matters that will be productive in the relatively near future (one to three years); (3) the application of the best available brains to all the important problems of the Commission."

May 16, 1951: Industrial Reactor Studies

The AEC made known that it would accept four proposals for "special studies of the practicability of business and industry building and operating reactors for the production of fissionable materials and power." These proposals were submitted by eight corporations, working in pairs and with each pair including at least one utility company:

1. Monsanto Chemical Company
   Union Electric Company of Missouri
2. Detroit Edison Company
   Dow Chemical Company

3. Commonwealth Edison Company
   Public Service Company of Northern Illinois
4. Pacific Gas and Electric Company
   Bechtel Corporation

The companies were to "determine the engineering feasibility of their designing, constructing, and operating a materials and power producing reactor." Moreover, they were to "examine the economic and technical aspects of building this reactor in the next few years."

May 1, 1952: Office of Industrial Development

The AEC established a new office, under Dr. William Lee Davidson, "to aid in the administration of the industrial participation program—involving studies of power generation—and to expand the areas in which all types of industry may find an interest in the national atomic energy program."

"The Commission's program of industrial development will be a two-way exchange. We want to make sure that the developments in the national atomic energy program which may have application in industry are promptly made available to the people interested."—from statement by Marion W. Boyer, General Manager, Atomic Energy Commission, May 1, 1952.

Recommended: "That the present cooperative arrangements between the Atomic Energy Commission and privately owned electric utility companies and other interested companies and groups for developing economical ways to obtain electric power from atomic sources be continued, and that the tempo of development work in this field be kept at the maximum level permitted by urgent security demands upon supplies of fissionable materials and technical personnel engaged in the atomic energy program."—from "Resources for Freedom," a Report by the President's Materials Policy Commission, June, 1952.

Summer, 1952: Study Group Reports

By mid-1952 each of the four pairs of companies engaged in the industrial studies had submitted to the Commission some form of report. The AEC made known that it was in process of studying each report.

"Should not the Commission make a new, and a determined effort, without compromising legitimate military secrets, to declassify those facts which are essential to informed public judgment on a proper policy for full industrial use of atomic energy? Specifically, should not the Commission declassify at least portions of the four reports on industrial participation in the reactor program filed with it by eight private firms?"—from remarks of Oscar M. Ruebhausen, Chairman, NYC Bar Assn. Committee on Atomic Energy, before National Industrial Conference Board, NYC, N. Y., October 17, 1952.

October 18, 1952: A Second Round of Industrial Studies

In April 1952 the Dow-Detroit Edison companies proposed that they undertake a further study to be jointly financed, partly by private funds and partly by public funds. The Commission accepted this proposal, which requires the government to defray about three-quarters of a million in expenses and the two firms about one-quarter million. On October 18, 1952 the AEC announced that eleven more companies would work with Dow-Detroit Edison in the same study

program. Meanwhile, two additional companies—Pioneer Service and Foster Wheeler—were starting a separate power survey, and four others had indicated interest.

"The Commission had two possible decisions it could have made when it was approached by these groups: It could have said, 'Go away, you bother me,' or it could have said, 'Come in and look around.' It chose to say, 'Come in and look around.' "—from remarks of former Commissioner T. Keith Glennan at the Manufacturing Chemists Association, New York City, New York, November 25, 1952.

December 1952: Role of AEC Contractors

A number of companies now have actual contracts with the AEC to perform work in the reactor development field. Some of these companies possess extensive knowledge concerning possibilities of atomic power for industrial purposes. To date no AEC contractor has suggested that it undertake an atomic power project partly or wholly at its own expense.

"It is very important to be inside the stockade—that is what these contracts permit. As long as this business operates behind a uranium curtain it is a good idea to be behind it, so as to be able to keep abreast of things. I say this not cynically; I say this as a matter of practical judgment on the part of business executives.

"And then if some day private opportunity really comes, then you will have the trained personnel and the backlog of experience that would enable that private opportunity to be exploited. . . .

"Now, just a word about power production, which is a second important category of potential private investment of funds. My own conclusion is this: I wouldn't advise anybody who is responsible for private investment under present conditions to put his money or the money of those who rely upon him into the development of power plants employing fission as a source of heat.

"I feel that the coming of atomic power is inevitable; that a good job is being done in that direction despite the necessary distractions of military considerations; that the effect on our power supply of atomic power will be supplementary rather than revolutionary, or to supplant existing methods.

"I believe the technical and engineering problems will be solved and rather quickly. It may well be that a whole new approach to this subject may develop in the course of the next few years not requiring the methods that are now being followed. And I believe that in time strictly private investment, genuine private investment will find a way of bringing down these present very, very great costs. The costs will come down when people have their own money at stake.

"But there are serious obstacles in the way, which seem to me to make it imprudent at the present time for anyone to consider seriously putting substantial private money into this field."—from remarks of David E. Lilienthal, Former Chairman, U. S. A. E. C. before National Industrial Conference Board, New York City, New York, October 17, 1952.

C. ATOMIC POWER AND THE "PLUTONIUM QUESTION"

1. Does the United States Need More Active Material—U-235 and Plutonium—Than Is Now Planned?

The nation is undertaking a new atomic construction program that will furnish about one-half the production rate capable of being achieved, according to official AEC feasibility studies completed in 1951. The construction cost of the program actually under way will be about $4 billions over a period of some years. The construction cost of the full program deemed feasible in the 1951 studies has been variously estimated at $7 billions and $10 billions over a period of some years.

"But I think it is quite obvious that the current atomic arms race cannot go on forever. Somewhere along the line there is a point where the law of diminishing returns begins to operate. And somewhere, not too far beyond this point, there is another point where we will have acquired all of the weapons we would possibly need to destroy, not only the industrial ability of an aggressor to make war, but also his forces in the field.

"When this point is reached, and it is *not* in the *unforeseeable future*, the question arises: 'What do we do then?' Do we go on turning out more and more fissionable material and more and more weapons, as we are doing now? Or do we say to ourselves, 'Now we have enough; no matter how many bombs our competitor may choose to make, we have enough.'

"I think we should do the latter."—from remarks of Gordon Dean, Chairman, Atomic Energy Commission, at the American Bar Association, San Francisco, California, September 17, 1952.

"No matter how many [atomic weapons] we might come to possess, we would need and could profitably use far more—in the event we were attacked."—from remarks of Senator Brien McMahon, Chairman, Joint Committee on Atomic Energy, Hartford, Connecticut, June 14, 1952.

"Our effort must be more productive than that of our probable enemy; if this requires an all-out effort on our part, then this is what we must do. But this program [i. e., the 1953 atomic expansion program] is by no means an all-out one."—from testimony of General Omar Bradley, Chairman, Joint Chiefs of Staff, before House Committee on Appropriations, June 16, 1952.

2. In Particular, Does the United States Need More Plutonium Than Is Now Planned?

The current atomic expansion program calls for spending several times as much money in construction of new facilities to produce uranium–235 as in construction of new facilities to produce plutonium. One purpose of this allocation was "to leave room" for more plutonium which private enterprise might furnish from dual purpose reactors also producing power.

"Another problem which has occupied considerable Committe time is the ratio between plutonium and U–235 output; for a healthy balance between the two is essential to national security."—from "Report of the Joint Committee on Atomic Energy to the Congress of the United States," October 19, 1951.

"I would like to remind you, too, as a further obstacle, that if the government purchases plutonium as a by-product of a power plant from a private concern, then regardless of what the contractual provisions with the government are, as a practical matter that plutonium, purchased from a private concern, must bear the correct price and cost ratio to uranium-235 made in government plants using the gaseous diffusion method,"—from remarks of David E. Lilienthal, former Chairman, Atomic Energy Commission, before National Industrial Conference Board, New York City, New York, October 17, 1952.

3. If the United States Needs More Plutonium, Should the Government Promise To Buy It From Private Industry?

The original concept underlying the "industrial participation program" was that private companies might build, at their own expense, reactors producing both power and plutonium. This concept assumed that government would purchase plutonium from the companies, thereby promoting national defense and also encouraging private development of atomic power.

"What has interested industry is the fact that the fissionable material, plutonium—for which there is a great demand in the Government for use in weapons manufacture—is made in reactors, and these firms feel that if they can build reactors that produce plutonium for the Government and power for commercial use simultaneously, they may possibly make the power they produce economically competitive.

"There is a lot of merit to this idea, and we are going to do all we can to help make it work."—from remarks of Gordon Dean, Chairman, Atomic Energy Commission, before Electric Power Engineers, French Lick, Indiana, October 12, 1951.

"Obviously the crucial question for such a plant as this is the question of how much plutonium does the Government require for military purposes and how long is it going to continue to buy plutonium?"—from remarks of Commissioner Henry D. Smyth, Atomic Energy Commission, before the American Mining Congress, Denver, Colorado, September 25, 1952.

4. All Plutonium Is Today Manufactured by the Government. Would the Spur of Competition From Private Enterprise Be Desirable?

Government manufacture of plutonium is still carried out through contract agreements whereby the contractor is reimbursed for all costs. Various misgivings have been expressed about the efficiency of such arrangements from the standpoint of incentive to reduce costs, increase output, and take well-calculated technical risks.

"We feel we can not only produce more plutonium for our national security program, but perhaps also make it at a lower cost to the government and the nation. * * * There is no gainsaying the fact that savings accrue from the techniques and methods of the free-enterprise system. The profit incentives alone give the competitive system a definite edge over governmental operation of business, no matter how efficient the latter may be."—from remarks by Edwin J. Putzell, Jr., Secretary, Monsanto Chemical Company, before Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

"In spite of congressional investigations, monopoly tends to be a comfortable position. If unnecessary time is taken to reach a decision, there is no competitor here at home to move into the field ahead of you. If there are unnecessary men employed on a job, it's just part of the cost—there is no danger of losing money on the job. This lack of real incentive to reduce costs, tends always to leave the cost floating around at some level, not dis-

gracefully high, but not necessarily near rock bottom."—from remarks of Dr. Kenneth S. Pitzer, Dean of Chemistry, University of California, Berkeley, California, March 7, 1952.

"Let us take a hypothetical case. The Commission has under construction at some remote location a plant for producing fissionable materials in which it will have an investment of, say $4,000,000,000. In authorizing this plant, it would necessarily have committed itself to a particular production process. Now, let us imagine that tomorrow some hitherto unrecognized genius comes to the Commission with a new process—one which might do the same job, but at half the cost, in half the time, and with half the investment. Under free enterprise that plant would be built, just as automobile plants were built and superseded the carriage factories which previously provided the best in transportation.

"But what is a commission to do? Shall it appropriate another $2,000,000,000 for a new plant and write off as a loss the $4,000,000,000 previously invested? That investment was not a mistake. It represented progress with the best method available at the time it was made. But a not too sympathetic member of Congress might well raise the cry that the Commission had wasted $4,000,000,000 of the public's money.

"I do not know what the present Commission might do under these imaginary circumstances. I rather think it would have the intestinal stamina to authorize the new plant. But the historians of bureaucracy would contend that at least nine out of ten commissions would shut their eyes to anything of value in the new process and it would be quietly suppressed. Bureaucracy's face would be saved at the expense of the progress of the art."—from remarks of Henry K. Norton, President, Walter Kidde Laboratories, before National Industrial Conference Board, New York City, New York, October 16, 1952.

"The rate of obsolescence for power plants will be very great. A good many of the present producing facilities in this enterprise have been virtually Chinese copies of the very first; this won't go on. New methods may come fast."—from remarks by David E. Lilienthal, former chairman, U. S. Atomic Energy Commission, before the National Industrial Conference Board, New York City, New York, October 16, 1952.

5. How Would the Price Paid for Plutonium Be Determined?

Various possibilities as to a pricing formula have been tentatively discussed, including the following: (1) The Government would pay some percentage of the price which it now spends to produce plutonium at Hanford; (2) the Government would pay a price equalling the actual cost to the private company; (3) the Government would pay an amount equal to the "military value" of the plutonium, a "value" to be calculated from "substitution curves" reflecting the cost of alternate military equipment if the added plutonium were not available; and (4) the Government would at first pay considerably more than it now spends for Hanford plutonium, so that the plant could be rapidly amortized—but thereafter, during the remainder of the plant life span, the Government would pay considerably less than it now spends for Hanford plutonium.

"The problem of purchasing plutonium carries along a companion problem—that of the pricing formula. The price formula should certainly provide a profit incentive covering the entire operation, that is, it should take into account both the plutonium and the power sold as a package on which the seller could make a profit. But how would the price be worked out to assure adequate incentive without entailing unjustified subsidy of atomic power? Can a system of competition among interested companies be fashioned to strike the appropriate balance of these factors?"— from remarks of Commissioner Eugene M. Zuckert, Atomic Energy Commission, before the American Chemical Society, Chicago, Illinois, September 11, 1952.

"The more we 'pay' for plutonium, the cheaper the power becomes. To take an extreme position, if some persuasive individual could talk the military into setting a really high figure for plutonium, we might have power for 'nothing'. My point is that cost and accounting principles and procedures are yet to be developed for the entirely new conditions involved in the use of fissionable material as a fuel.

"Development of these procedures illustrates one of the very difficult problems that we have to face in government, because the government just isn't set up to handle problems of this kind. The government, by and large, operates to give you the lowest apparent cost next year. It is not designed to give you highest profit in the long run. In fact, there is nothing in the governmental money mechanism that gives you a chance to approach such a problem by planning and operating to make the most of an opportunity financially.

"On the other hand, industry wants a 'maximized' profit over the long run and is willing to make short-term investments to that end. Government worries only about next year's budget, trying constantly to beat that down as much as possible. For this reason you find yourself relatively unable to make long-range investments with high short-term costs which might make it profitable to get nuclear power plants on an economic basis. Here, then, is a governmental, legal, and accounting problem—a challenge to lawyers, accountants, and public administration people.

"Here is a small facet of the problem. The plutonium of high value which is produced in the fuel elements of a reactor is, in effect, stored there until removed by chemical processing. What should be the interest charge on that fissionable material? This is something which one can argue about. You can say that the material has a certain cash value and therefore the interest should be carried. This would make costs higher. You could also say that, since plutonium is wanted for military purposes, interest should be charged for the time that it would take you to get the initial charge of plutonium out of the reactor and back into a stockpile. This would be a short-term loan and would reduce interest charges. I don't know all the answers, but I do know that a group like this, at one stage or another, has to come to grips with such problems."—from remarks of Dr. Lawrence R. Hafstad, Director of Reactor Development, Atomic Energy Commission, before Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

6. Could the Government Justifiably Guarantee To Buy Plutonium Over a Period of Years?

Some consideration has been given to a close-out arrangement whereby, if the government at a future date found additional plutonium no longer needed, it would pay to the private firm a predetermined cancellation charge. This approach would be analogous to the cancellation procedure written into existing contracts under which private industry furnishes conventional electric power to atomic installations.

"For such coproduct production, the feasibility of industry undertaking a greater role in power development might depend on the assurance the AEC can give of a guaranteed market for plutonium during the next 10, 15, or 20 years. Before private investment could be attracted to this field, assurance—based on sound contracts—would have to be furnished that the Government would continue to need plutonium.

"Such a long-range buying plan should also consider the interest of the taxpayer and fairness to all companies concerned. If the military and civilian uses of plutonium enable us to give only a limited guarantee for a period of years, there would be the question of whether we would be justified in buying plutonium for stockpiling beyond our needs, foreseeable at the time. Or, the result might be that the number of participants in the program must be sharply limited, presenting the problem of how to select companies which would be allowed into the circle. * * *

"There is another possibility. If the day should come, which all of us—no matter how doubting we might be—fervently hope will come, when world

peace is a reality, when international control of atomic weapons succeeds, or at least, when international conditions are more tranquil than they are today, would there be a need for the Government to continue buying plutonium?"—from remarks of Commissioner Eugene M. Zuckert, Atomic Energy Commission, before the American Chemical Society, Chicago, Illinois, September 11, 1952.

"When considering long-term contracts to produce plutonium—or almost any other product—some thought should be given to the inclusion of a clause granting the right of cancellation to the contractor, as well as to the government. It is standard practice for the government to have the right of terminating production contracts, usually on very little or no notice. Over a long period of years—twenty or twenty-five—during which a company has agreed to manufacture plutonium, many unanticipated developments may occur which could very markedly affect the contractor's ability to continue with the agreement. It would seem only right and just that, barring all-out war or extreme national emergency, the contractor should be able to exercise a right to terminate the contract on reasonable advance notice."—from remarks of Edwin J. Putzell, Jr., Secretary, Monsanto Chemical Company, at the National Industrial Conference Board, New York City, New York, October 16, 1952.

7. Is It Desirable To Start a New Industry Dependent Upon Government for the Purchase of Plutonium?

Some of the interested individuals who have publicly discussed atomic power development raise questions about an approach which relies partly upon a product other than power itself for economic justification.

"Our Government is the only customer for plutonium at present, although perhaps other Governments would like to buy some. So, it seems to me, such plants could live economically only so long as the Government guarantees the market and price for plutonium.

"In my opinion, this situation does not constitute a sound basis for an atomic-electric power industry. Certainly, barring war, at some time in the future our atomic-bomb stockpile should reach an adequately high peak, and the Government would not then be justified in continuing to purchase the plutonium output. It will probably be wondering what to do with its own plutonium and U–235 production plants. Atomic-electric power will be really economically sound only when it can compete with conventional electric power without requiring a Government-supported weapons market. It could not do that today—unless in some very peculiar and unusual circumstances—nor, in my opinion, for a good many years to come."—from remarks of Harry A. Winne, Vice President, General Electric Company, at Albany, New York, October 30, 1952.

"If the buying of plutonium were stopped, it is easy to imagine the dislocation to civilian industries that would have sprung up around reactor sites to utilize atomic power. With a sudden stop order on plutonium buying, and the resultant sharp increase in the cost of power, what means could be devised to avoid or minimize dislocations?"—from remarks of Commissioner Eugene M. Zuckert, Atomic Energy Commission, before the American Chemical Society, Chicago, Illinois, September 11, 1952.

"The dual-purpose reactor, in which power and fissionable materials would be produced together, may offer opportunities for private investment. However, it is plagued by the dual-purpose problem which plagued the T. V. A. You have a multiple purpose facility. In the case of the T. V. A. you had a dam for power, flood control, and navigation. Much of the debate was centered around how much of the dam was really chargeable to power, and how much to flood control, and how much to navigation. The dual-purpose reactor raises the same problem. How can you divide the capital as between power and as between refining? How can you adjust the price as between power and refining?"—from statement by Carroll L. Wilson, former General Manager, Atomic Energy Commission, in Panel Discussion, Michigan-Memorial-Phoenix Project Conference, June 27, 1952.

8. What Policy on Plutonium Will Bring About Economic Atomic Power Most Quickly?

Most, though by no means all, official and private thinking has been along the lines that the fastest route to future reactors producing power only on a commercially competitive basis is through interim reactors producing both power and plutonium. These interim reactors would presumably furnish the experience, cost data, and advances in the art necessary for major progress and still "pay their own way."

"I think that the only way we will get in the near future any economic electric power from nuclear energy is for the military value of plutonium to continue to bear a large part of the cost, or—putting it another way—for electric power to reduce the cost of plutonium somewhat. It is my hope that during the transition period, when the co-products will be sharing costs, the technology will be improved to such an extent that costs will be drastically reduced and we can begin to operate on the completely civilian leg of the system."—from remarks of Dr. Lawrence R. Hafstad, Director of Reactor Development, Atomic Energy Commission, before Michigan-Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

The hope, then, is that if plutonium can be produced for the Government and if the price received for the plutonium can be applied against the cost of producing the power, the power can be made economically competitive. If this can be done, it obviously would give private industry a chance that it otherwise might not have to get into the atomic-power business during the current high-cost developmental phase.—Remarks prepared by Gordon Dean, Chairman, United States Atomic Energy Commission, for delivery before the Chicago Association of Commerce and Industry, Hotel Sherman, Chicago, Ill., February 1, 1952.

"Someone must build and operate a nuclear power plant; we will never solve the problems by engineering and research alone—we must have actual experience. * * *

"Such a project will hasten the day when nuclear fuel may be competitive with other fuels on a peace-time basis because it will furnish the opportunity for developments that can come only through actual experience."—from remarks of Murray Joslin, Assistant to President, Commonwealth Edison Company (Chicago) before National Industrial Conference Board, New York City, New York, October 16, 1952.

"Whatever the value and the interest in proceeding with present developments of ideas for such plants, in the end hope for nuclear energy as a more or less permanent economical source of power, must rest on the straight power reactor and the breeder reactor. And the optimism of recent months, however justified, has not grown particularly out of any spectacular developments in relation to such reactors. As to them, while we are certainly ahead of the point where we stood when people were saying, several years ago, that it would be a matter of decades before we had economical power, there is no reason for believing that we are unexpectedly further ahead."—from remarks by Philip Sporn, President, American Gas and Electric Company, before National Industrial Conference Board, New York City, New York, October 16, 1952.

Because of the vital role which plutonium plays in the national-defense program, a dual-purpose plant would have to be designed principally as a plutonium-production plant. The design of the plant would be maximized for plutonium production at the expense of maximum power production, because there are definite design conflicts.

Location of such plants would be severely restricted to conform to defense policies.

In order to avoid excessive losses of the vital plutonium, the fuel elements would have to be discharged long before their value as fuel had been exhausted.

The dual-purpose plants would be quite large installations, and in addition some of their components would need to be over-designed to assure steady use under emergency forced-draft operation.—from "A Prospectus for Development of Atomic Power Through A Single Purpose Experimental Industrial Reactor (SPEIR)," by Dr. George L. Weil, September 13, 1952.

"There is another area of nuclear reactor development, however, which could rather soon be put on an economic basis, and which I regard as an attractive alternate to the colossal plutonium-plus-power-schemes as a way for industry to get a start in nuclear energy. I refer to Mr. L. R. Hafstad's recently reiterated suggestion of small, cheap nuclear power packages for use in remote localities where power is now very expensive."—from remarks by Dr. Alvin M. Weinberg, Director of Research, Oak Ridge National Laboratory, in *Nucleonics*, November 1952.

9. What About Tritium, Uranium-233, RW Agents, Other Isotopes, and Fission Products?

Plutonium is by no means the only important material which could be manufactured in dual purpose reactors also producing power. The reactors could be designed to produce power and tritium, or power and uranium-233 from thorium, or power and radiological warfare agents. Tritium is a material of fundamental interest in the hydrogen bomb program; U-233 is like plutonium and U-235 in that it could be used as the active material for an atomic bomb; and RW agents also might possibly figure in future military operations. In other words, the so-called "plutonium question" is a short-hand term used for convenience. It could as well be called "the tritium question" or the "U-233 question" or "the RW question."

Over and above power, and over and above plutonium or tritium or U-233 or RW agents, dual purpose reactors could produce certain quantities of radioactive isotopes such as the AEC itself now ships to private users throughout much of the free world. Moreover, all reactors of any type produce fission products, and these, too, may eventually be used commercially.

"The development work on piles for the production of U-233 which has been started should be continued. * * * Nuclear fission bombs of greatly improved efficiency are certainly in sight, and thermo-nuclear bombs of ten-thousand-fold greater power may even be feasible. * * * Studies of the possible use of fission products as radioactive poisons should be undertaken at such priority as is necessary for military security. * * * Attention should be given to the construction of small enriched piles which would be especially useful for scientific and possible commercial applications. * * * The Government should pursue a policy of vigorous encouragement to the development of a strong nucleonics industry."—from Report of the Committee on Post-War Policy, Dr. Richard C. Tolman, Chairman, December 28, 1944.

D. WHICH PATH TO ATOMIC POWER?

1. The Monsanto-Union Electric Approach: Government Would Build a Pilot Plant Producing Power and Plutonium, Whereupon Private Industry Might Build at Its Own Expense the Full-Scale Plant

Dr. Charles Allen Thomas' speech of June 11, 1950 helped bring about the "industrial participation program" and the study which his own company, Monsanto, undertook in combination with Union Electric. In mid-1952 Mr. Edwin J. Putzell, Secretary of Monsanto, commented:

"A year ago, when we approached this study of the feasibility of a combined plutonium and electric power producing reactor, there were three broad areas of questions:

"There were technical questions, there were economic questions, and there were legislative or legal questions that had to be answered.

"Monsanto and Union Electric now have been able to give the A. E. C. an only slightly qualified 'yes' in answer to the question, 'Is such a project technically and economically feasible?' Only recently, we reported to the Commission that the investigatory phase is virtually completed; that, in our opinion, now is the time to start the design and then the construction of a pilot plant.

"I do not want to misrepresent our position; Nuclear generated electric power is still perhaps four or five years away, measured in terms of full-scale producing units. But, we are ready to commence preliminary studies and work toward a pilot plant. Having confirmed the technological answers, the economic answers are bound to follow under our competitive system. * * *

"As a result of its feasibility studies, Monsanto and Union Electric have proposed that the AEC embark upon the design of a pilot plant reactor as soon as possible. Time being of the essence, we believe the government should construct and own the plant until the question is decided whether the present law prohibits ownership of facilities which would produce fissionable materials in the amounts which such a pilot plant would make. In addition, the technical data obtained from such a plant would be usable in the reactor development program of the Commission. Then, too, in the interest of time, the efficient use of presently existing facilities and experienced technical manpower indicates that the power plant should go forward promptly under government auspices and with its funds. For our part, we propose to have a full share of responsibility in the design, construction, and operation of the pilot plant and want to cooperate with the Commission at every step in the program.

"However, our desire to participate doesn't end there. We believe that once the pilot plant developmental stage is completed and the remaining technical questions answered, private industry will invest its own funds in the construction and operation of a full-scale plant for the production of power and fissionable materials. To reach that end, though, several changes may have to be made in the Atomic Energy Act. Undoubtedly, the Commission and the Congress will find ways to make the necessary changes; but here again in the interest of maintaining our country's leadership in atomic energy, time is important."—from address by Edwin J. Putzell before Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

2. The Dow-Detroit Edison Approach: Private Companies Would Continue Study and Research, Partly at Their Own Expense, Whereupon They Would Themselves Finance and Build a Full-Scale Power-Plutonium Plant Without Going Through the Pilot Stage

Dow-Detroit Edison are the two concerns currently spending $250,000 from company funds to carry on further study and research in cooperation with the AEC. In mid-1952 Mr. Walker L. Cisler, President of Detroit Edison, commented as follows:

> "It seems to me that from the standpoint of industry this whole matter of the development of atomic energy for use in industry must be approached on two fronts—first, the technical front, and second, the legal front. I believe that those should move forward simultaneously, and progress should be made in both aspects as rapidly as possible. I think it's extremely important in view of the world situation, and the urgency of the need for fissionable materials, that we take a distinct step forward which would bring into being a type of reactor that will be productive of large quantities of strategic materials which are of importance both from a weapon standpoint and as a fuel for the propulsion of marine vessels or aircraft of a military nature, as well as at the same time producing large quantities of heat energy. I believe that making a step forward into the type of breeder reactor, that will utilize and make available the materials which are now waste materials or materials of lower quality, will enable the production of greatly increased quantities of plutonium and large quantities of heat energy. In taking that step forward, it means that private capital must really take a risk, a significant risk, but if the risk is worth what many believe it is, then capital is justified in taking that risk. I believe that the risk may not prove to be so great as it might seem and perfectly within the justification of private capital. Our progress in this field is sufficiently firm that we will go to an actual plant without going through the pilot stage."—from statement of Walker L. Cisler, President, Detroit Edison, at Panel Discussion, Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

Some three months later Mr. Cisler again commented, indicating that plutonium produced in the plant he foresees might not inevitably have to be ear-marked for bombs but that such material as this might be wanted for use in atomic submarines, surface vessels, aircraft, and the like and also for use by "an expanding nuclear power industry." This was the first authoritative suggestion from private industry that "the plutonium question" may not have to be solved mainly by government and mainly on the issue of whether the government needs more plutonium for bomb purposes. Mr. Cisler said:

> "It is obvious to all that the economics of atomic power are dependent to a large extent on future reactor developments with respect to types of fuel, by-products, and construction costs. Present indications are that these problems can be worked out in a favorable manner. * * *
>
> "We are convinced that industry will participate to the fullest measure if it can do so in accordance with the free enterprise system, if it has the opportunity to invest private funds and to enjoy the results of its efforts. This means that consideration must be given to certain legal aspects, particularly to those portions of the atomic energy law which require governmental ownership of facilities and fissionable materials.
>
> "The approach of The Dow Chemical Company and The Detroit Edison Company to their joint project always has been that of private industry. They are proceeding with the second phase of their project as rapidly as possible. Progress has been greatly accelerated by the loan of experienced men from several other electric power systems and industrial companies. If the technical problems can be resolved, the two companies would like to build and to operate a commercial sized reactor plant using private capital and without recourse to governmental funds.

"While it is recognized that the sale of by-products is important, and even may be the controlling factor in a nuclear power plant, it is not considered at this time that a definite price for such by-product established in advance, is necessarily a prerequisite for proceeding with this program.

"It is expected that not only will there be a possible market for weapons purposes, but that there will also be a market for the excess fuel to meet the requirements for mobile reactors and for the requirements of an expanding nuclear power industry."—from remarks of Walker L. Cisler, President, Detroit Edison, before National Industrial Conference Board, New York City, New York, October 17, 1952.

3. The Commonwealth Edison Approach: Government Would Build a Reactor Producing Power and Plutonium While Private Utilities Build, at Their Own Expense, Generating Equipment To Convert the Power to Electricity for Sale to the Public

The Commonwealth Edison-Public Service industrial study brought forth the concept of a joint government-private project. Speaking for the two utilities Mr. Murray Joslin, Assistant to the President of Commonwealth Edison, commented:

"Now our plan is as follows—and please keep in mind that it is only in the discussion and development stage and has not been submitted to the AEC as a formal proposal:

"The reactor power plant would be built on a site acquired by us, suitable for a conventional power plant and connected to our general transmission system. The AEC would pay for and own the reactor proper. We would pay for and own the conventional facilities which obviously would consist of turbo-generators, condensers, switchgear, etc. Certain 'intermediate' facilities such as the heat exchangers would be paid for by AEC through a grant in aid of construction. * * *

"The outstanding features of our plan, and our hopes for the facility it might bring into being, may be summarized as follows:

"1. The plan requires no legislative changes at either the national or the local level.

"2. Under it we would invest our funds in the so-called conventional facilities.

"3. We would assume all the financial risks that are normal to our business plus a lot of problems that are anything but normal.

"4. We would be protected from the abnormal financial risks that we could not rightfully assume as a utility.

"5. The facility would be a substantial producer of fissionable material for the military so long as stockpiling is continued.

"6. The facility would be a source of income to the government when stockpiling is discontinued and it is operated for power alone, but of course the government would bear the cost of the fabricated fuel elements.

"7. It would be a valuable national defense facility because we would be committed to going on a military plutonium production schedule whenever called upon. As those familiar with the technology know, this can be done on short notice with no unusual expense.

"8. The beneficiaries of the project would be:

(*a*) The country at large for its plutonium production capacity and its contribution to technical knowledge.

(*b*) The users of electric utility service generally, if it will hasten the day when nuclear fuel can be employed to reduce the cost of producing electricity."—from remarks of Mr. Murray Joslin before National Industrial Conference Board, New York City, New York, October 17, 1952.

4. The George Weil Proposal: The Former AEC Assistant Director of Reactor Development Has Suggested That a Non-Profit Foundation Be Established by Private Groups, for the Purpose of Building a Pilot Plant To Produce Power Only

Dr. George Weil recently resigned from the AEC Reactor Division to advocate a new and largely private attack upon atomic-power prob-

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lems. This approach looks toward power-only reactors and stresses the need for gaining experience and cost data through construction of a pilot plant. Dr. Weil writes:

"The immediate objective is to determine the performance and economics of power production—through single-purpose power reactors designed solely to measure and study realistically the economics of atomic power.

"The program proposes a direct attack on the major development and engineering problems associated with minimizing the cost of power by establishing as its first task the design, construction, and operation of a single-purpose experimental industrial reactor (SPEIR).

"Public money has not taken this first practical step toward nuclear power.

"Private enterprise has not, and probably will not, for some years to come.

"But a combination of public, business, and philanthropic money could make an investment which would be a real achievement in public service—and point the way to further service and profit in the future.

"It is proposed to establish a nonprofit organization which initially will be responsible for executing and administering the technical program by contract. Later the SPEIR project directly, through its own staff, would be responsible for operation of the plant, and its use in providing information on performance and economics of operation and in further development and engineering work.

"SPEIR would focus and coordinate the interests and financial participation of governmental agencies and both profit and nonprofit private groups.

"The design of the single-purpose experimental industrial reactor would be selected from a number of possible existing preliminary designs. The basic technology of each of these has been sufficiently developed under the Atomic Energy Commission's program to allow start of construction of a plant in about 1 year from time of authorization of the project. Construction would require about 2 years for completion. Following completion of construction, provision is made for 2 years of study. It is estimated that funds for the project would be required as follows:

Research and development (5 years)	$10,000,000
Engineering design	1,000,000
Construction	9,000,000
Total	20,000,000"

—from "A Prospectus for Development of Atomic Power through a Single Purpose Experimental Industrial Reactor (SPEIR)" by George L. Weil, September 13, 1952 (see Appendix A for full text).

5. The "Power Package" Approach: Government Might Build a Small-Scale System in an Area Where Present Power Costs Are High and Itself Sell Electricity From Such a System to Private Consumers

Until Spring, 1950 the Atomic Energy Commission planned to build an experimental power-breeder reactor near Schenectady, New York. This reactor would have furnished power in significant quantities. Except for the Spring, 1950 decision against starting construction, government might today be facing the question of what to do with actual power it had produced.

The Commission is currently considering a partly similar "power package" reactor project:

"Recently we completed construction on, and placed into operation, a new reactor which is now working successfully. When this reactor was first thought of, it was believed that it would take $50 million to build it. The actual final construction cost was not $50 million but $20 million, and now I am told by some of our scientists that they feel they could take the lessons learned on that reactor and build a somewhat smaller but essentially similar machine, without the costly research features of the original one, for as little as $5 million and possibly even less.

"When you get down into this range, the cost of the power such a machine would produce begins to become interesting—not because it would compete generally with power from coal, oil, gas, and falling water, but rather because it looks like it might begin to become competitive in a few isolated locations where normal power costs are extremely high.

"I hope my references to this specific example will not be misunderstood. I am not talking here about the kind of a reactor that would be suitable for a big central power station, feeding kilowatts by the millions into a utility network. That is what the industrial study groups are pursuing. What I am talking about here is a relatively small machine that would produce kilowatts numbered in the thousands but sufficient to perform a useful purpose in undeveloped or underdeveloped areas which are remote from normal sources of power, and which are now either priced out of the power market or can afford only a marginal supply at best.

"In any event, this is an interesting and challenging possibility, and it is a possibility which the Commission is now very seriously looking into."—from remarks of Gordon Dean, Chairman, Atomic Energy Commission, before the American Bar Association, San Francisco, California, September 17, 1952.

"I have received your letter of November 25, 1952, asking for a brief report on the survey of high power cost areas being made by the Department of the Interior at the request of the Atomic Energy Commission.

"Our Division of Reactor Development has a number of conferences and projects scheduled during the month with the Department of the Interior and the Federal Power Commission. Out of these projects will come the information we will require on our survey of high power cost areas.

"This initial work should be completed by the first of January and shortly after that time we will be pleased to submit a report to your Committee."—Letter from Marion W. Boyer, General Manager, Atomic Energy Commission, to Joint Committee on Atomic Energy, December 4, 1952.

6. The Eureka Proposal: Nevada Mining and Ranching Interests Have Asked That the AEC Locate a Power-Plutonium Reactor Near Eureka, Nevada, With the Power To Be Used To Pump Water From Local Mines and Also To Assist Desert Irrigation

In the Eureka area of Nevada the cost of power from conventional sources is high. Local groups therefore see in atomic power an opportunity to reduce costs. Arguing that a power-plutonium reactor should be situated near Eureka, they list the following points in a recent report to the AEC:

"1. The location is within a great desert area, the nearest population center being Ely, Nevada, 77 miles distant.

"2. Although the location is remote it is reached by paved main line highways and has good telephone and telegraph connections.

"3. The Eureka District is one of the most attractive potential gold-silver-lead-zinc producing areas of the United States. Recent development of a large body of ore in one mine alone apparently will justify the installation of a dual-purpose reactor to supply power.

"4. Diesel-electric power, the only power presently available, costs three cents per kilowatt-hour. The A. E. C. could furnish power for much less, and yet obtain a rate far in excess of what could be paid by large commercial firms in populous centers.

"5. Disposal of radioactive wastes from the reactor should be a minor problem because of favorable location.

"6. The financial backing of Eureka Corporation is strong and it would make a long-term agreement.

"7. The Eureka Corporation has facilities for construction, operation and management of a reactor power plant, and a 6,000 kilowatt power plant ready for immediate operation.

"8. Initial experimentation could be carried on without interference, and all state agencies would cooperate to the fullest extent.

"I have another statement from the Chairman which I think should be read into the record at this stage. It is a letter from Chairman Dean to me. 'Dear Mr. Hafstad: I am glad to learn that you will have an opportunity next week to explore with the members of the Public Works Committee of the Senate some of the problems which face the Commission in its endeavor to secure useful power from atomic energy. There has been little question in the Commission's mind that in high-cost fuel areas reactors might appropriately supply power. I hope, however, that you will be quite frank with the committee in explaining some of the difficulties, including the legislative changes, that will be required before we can induce private enterprise to come in and participate with risk capital in the construction of such power units.' "—from testimony of Dr. Lawrence R. Hafstad, Director of Reactor Development, AEC, before a Subcommittee of the Senate Public Works Committee, Henderson, Nevada, October 10, 1952.

7. The "All-Government" Approach: The AEC Might Build the First Plant and Generate Electricity for Its Own Use Within the Atomic Program

The AEC is constructing new facilities for the manufacture of plutonium. If it were possible to adapt some of these plants, or future government plants, so that they could produce power as well as plutonium, the Commission might meet part of its power needs for the atomic program from its own facilities.

"The best known example of reactors utilizing the neutrons for transmutation are the Hanford reactors which you have heard about. These are production reactors, used for producing plutonium for the atom bomb stockpile. Of course, large quantities of heat are also generated, but the temperature is so low that this heat cannot be utilized practically. Its removal is strictly a cooling operation; it is dumped in the Columbia River. Now, if we could run the temperatures of these Hanford reactors up somewhat, and begin to extract this heat at a temperature level enabling us to generate steam and then mechanical or electric power, it is conceivable that we might get a by-product credit for the power. This would have two values: (1) it would reduce the cost of plutonium by the amount of the credit for power and (2) it would begin to restore to the national economy the electric power which the Atomic Energy Commission is now withdrawing from the Nation's networks. Thus, production reactors offer a very promising direction of development."—from remarks of Dr. Lawrence Hafstad, Director of Reactor Development, Atomic Energy Commission, before the Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 28, 1952.

Far from being a producer of power today, atomic energy is actually one of the Nation's largest consumers, and the balance will be on the debit side for a long time to come. It has been estimated, for example, that our power requirements by the middle of 1953 will amount to about 2½ percent of the total installed electric power capacity of the United States—an amount equal to around 85 percent of the production capacity of the Consolidated Edison Co. here in New York—from remarks by Gordon Dean, Chairman, United States Atomic Energy Commission, before the New York State Chamber of Commerce New York City, June 7, 1951.

8. Various Spokesmen Have Raised the Possibility of Building Power-Only Plants in Friendly Foreign Countries

Since the cost of power from conventional sources is low throughout most parts of the United States, the thought has often been expressed that atomic power could more easily compete in high-cost areas abroad.

"It seems to me also that if it is possible to develop the peacetime use of atomic energy as a heat source for industrial purposes, it may give us one

of the best means of combating the spread of Communistic influence over the other parts of the world. There are other countries, with no great fuel resources like our own, which need atomic energy more than we do. When you think of some of the countries in Western Europe, such as the Netherlands, Belgium, and France, you will realize that.

"It is only a few weeks ago that the Queen of The Netherlands visited you here on the University of Michigan campus. I had occasion to talk with her on the subject of electric power and atomic energy. In brief she said, 'You know our coal reserves are rapidly dwindling and we must plan for the future supply of our heat energy needs.' She said she believes this problem can be solved only through the development of this new-found source of energy—atomic energy."—from remarks of Walker L. Cisler, President, Detroit-Edison Company, before the Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 28, 1952.

If reactor developments turn out successfully and costs can be reduced—and I am certain that we will be successful in these matters—there will be an increasing demand for stationary nuclear power plants. This demand naturally will arise first where present costs for electrical energy are high and this suggests that such a program may have an important place in any future Point Four programs—from remarks by Commissioner T. Keith Glennan, United States Atomic Energy Commission, at The American Society for Engineering Education, Dartmouth College, Hanover, N. H., June 24, 1952.

"Henry D. Smyth, member of the Atomic Energy Commission, said today the first nuclear power station may be constructed in some foreign country with financial help from the United States.

"Mr. Smyth suggested it might prove practical to finance the plant—huge enough to provide electricity for an entire city—from Point 4 funds. * * *

"The reason for a foreign site for the proposed plant he told reporters, involves the relative cost of competing steam or hydroelectric power sources. Power production in the United States is much cheaper than in some other countries he said."—from New York Herald Tribune, dated November 30, 1952.

"Q. Do you believe that a closer cooperation with other Atlantic Pact nations in atomic matters is desirable and possible without endangering national security?

"A. Yes, I do, particularly in the case of our traditional atomic energy partners, Britain and Canada, and also Belgium, upon whom we rely for a substantial share of our uranium supply. As you probably know, the Congress recently passed an amendment to the Atomic Energy Act which permits, subject to a number of safeguards, a rather wider interchange of information between us and our foreign friends than has hitherto been the case. We have already entered into one agreement with Canada under this amendment, and we are currently looking into the possibility of exchanges with the other countries where there would be a mutual advantage. We are also assisting Belgium in the training of technicians and in the transmittal of unclassified technical information."—from An Interview with Gordon Dean, Chairman A. E. C., November 1952 issue of Bulletin of the Atomic Scientists.

"Nuclear Reactor Asked.—A professor of nuclear physics at the Australian National University, Prof. (Chitterton), has suggested that a nuclear reactor should be built in Australia immediately, so that young scientists could be trained to take advantage of future developments in the peacetime use of atomic energy. Prof. (Chitterton), addressing the Royal Empire Society in Sydney, said that other small countries like Norway and Holland were building nuclear reactors, while Canada was already operating the best reactor in the world. Prof. (Chitterton) said it was obviously beyond Australia's short-term capacity to carry out large-scale research in the building of atomic power stations.

"It was desirable that any agreement for the sale of uranium to Britain and the United States should provide that information be made available

to Australia about the design of atomic power stations. Prof. (Chitterton) said that the development of atomic power for peaceful purposes held great significance for the future development of inland Australia. Small compact atomic power plants could be used to pump water over vast areas of the interior, raising the fertility of the land and making possible significant increases in food production. (Melbourne, Australia.)"—from Radio Monitoring Service, Melbourne, Australia, radio broadcast to North America, November 15, 1952.

E. POWER AND THE CONTROL OF ATOMIC ENERGY

1. Government Monopoly Versus Private Enterprise

On the broad policy questions as to the proper roles of government and industry, all shades of opinion are encountered. However, as the Chairman of the Atomic Energy Commission recently indicated, the point has not yet been fully reached where questions of broad policy on industrial uses arise in the context of specific and concrete alternative courses of action.

"So we are going to push forward in this field of peaceful uses. We have, of course, the choice of letting them ride along or pushing them. We are going to push them. And in doing so we are inevitably going to push into an area where a whole range of questions of basic public policy must be faced up to and resolved.

"Most of these questions revolve around the central fact that today atomic energy in this country is a 100 percent Government monopoly, and it is a monopoly because that is the law of the land. But if the peaceful uses of atomic energy are to be brought to full flower, and find a permanent and secure home in our economy, is it not true that the Government must relinquish at least part of its monopoly? We think it is. But, if so, how much of the monopoly can and should be relinquished? And how can this withdrawal be done neatly and smoothly without disrupting the weapons side of the program and without making room for abuses and inequities? And as it does withdraw, what rights can and should the Government leave behind to protect the over-all public interest?

"These are important, basic questions of public policy and they will ultimately have to be answered by the Congress, perhaps by the Congress that will be seated next year."—from remarks of Gordon Dean, Chairman, Atomic Energy Commission, before the American Bar Association, San Francisco, California, September 17, 1952.

"The interest of private industry in the possibility of building power plants using uranium as fuel has brought the Atomic Energy Commission face to face with a whole series of questions of a political and sociological nature * * * production of power either starts with normal uranium, in which case plutonium is an inevitable byproduct, or starts with uranium 235, in which case the initial fuel is identical with one of our atomic explosives and, therefore, predicates the manufacture of such explosive. *We cannot split the atomic energy industry in two parts, labeling one for military purposes and keeping it under Government control, and labeling the other for civilian purposes and releasing it to private industry.*

"The difficulty of separating military and civilian development in the field of atomic energy was recognized when the Congress drew up the McMahon Act under which we operate. The fundamental thesis on which this act is based is that the development of atomic energy was to be under a Government monopoly."—from an address by Commissioner Henry D. Smyth, Atomic Energy Commission, before the American Mining Congress, Denver, Colorado, September 25, 1952.

"* * * the major social, economic, and international considerations relating to the development of atomic energy, expressly recognized in the Act itself, appear to have been forgotten in the plangent urge to instate the enterprise system. And what has happened, one may ask, to the innocent notion that the benefits of atomic energy should accrue to the nation as a

whole—without the prior drain of private profits—since the resource itself was brought to fruition by public funds? Somewhere along the circular route of national policy this point got lost. Sooner or later the American people will demand to know where and why. The answer, I venture to say, will not be easy to frame."—from "The Atomic Energy Industry: An Experiment in Hybridization" by James R. Newman, The Yale Law Journal, December 1951.

"[A] question which is invariably asked when the proposals for industrialization of the atomic energy program are brought up is—Are we turning over to private industry for their own increased sales and benefit those ideas which were developed at the Taxpayers' expense and which rightfully belong to all the taxpayers? To a certain extent, this is the case. However, the information is available for any and all to partake of and to use in the best way possible. But more important, the present cost of the atomic energy program to the taxpayers of this country is of such proportions that the industrialization of the program will certainly result in a tremendous saving of future expense to the taxpayers; and at the same time he will reap the great additional benefits to be derived from industrialization. The taxpayer has not been hurt because the development of the motor car has been in private hands. On the contrary, because of the great stimulus of private competition, he has available to him at the lowest possible cost, the most advanced types of automobiles in the world. The same can be true in atomic energy."—from remarks of Stanley B. Roboff, Manager of Industrial Coordination, Atomic Energy Division, Sylvania Electric Products, Inc., before the National Industrial Conference Board, New York City, New York, October 17, 1952.

One road block to the advance of peacetime uses of nuclear energy is the restrictive features of the present Atomic Energy Act. This law was enacted in a time of stress and at the very beginning of the burgeoning atomic age. Some of its provisions would lead one to think it was written by men who believe in the socialistic principle that the state should control the means of production. Now that the people of the country have so clearly expressed their aversion to socialistic trends, we have reason to hope that a different approach to commercial development in the atomic-energy field will be encouraged, and the basic law amended so that, commensurate with national safety, this incalculable source of future energy will be open to incentive development and productive uses for peaceful industrial purposes under our American enterprise system.—from remarks of G. M. Gadsby, President, Utah Power & Light Company, November 14, 1952.

2. The Problem of Ownership

Debate on the broad policy questions centers most often upon ownership of fissionable materials and reactors—who ought to own them, government or industry, and whether, under the present law, satisfactory arrangements could be made for industry to proceed with private atomic power projects.

"The basic legal questions arise primarily out of Section 4 of the statute. That section defines the term production of fissionable material, and then it specifies that the Commission shall be the sole owner of all facilities for the production of fissionable material, other than certain facilities of a rather limited type. Without venturing a final legal opinion on a subject which may still be open to some argument, it seems evident that the prohibition in the statute appears to create a most substantial impediment to private ownership of the dual-purpose reactor which could produce both plutonium and power. Therefore, I think we must consider whether in this state of the law one could expect that any private enterprise would seriously consider investing substantial capital of its own in a facility of this nature."—from statement of Bennett Boskey, former Deputy General Counsel, Atomic Energy Commission, before Discussion Panel, Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

"In view of the provision of the statute, if any private group were to endeavor to raise the large sum of money required to build such a facility, one of the prior conditions I assume would be that there is to be no doubt that the private enterprise, in using its own capital and building the facilities, should be able to own it. Any cloud on the title of the facilities would seem to me to interpose a very serious and perhaps impassable barrier to raising the capital necessary. In view of the very tentative judgment regarding the nature of the prohibition created by Section 4 of the Atomic Energy Act, I would suppose that, before any sum of money would be raised and invested in such facilities, it would have to be quite clear that they do not belong to Uncle Sam but belong to the people who provide the capital."—from statement of Carroll L. Wilson, former General Manager, Atomic Energy Commission, before Discussion Panel, Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

"First of all, the question of control of the production and use of source and fissionable materials is important. However, there is no reason why, with the industrialized atomic energy program of the future, strict control of fissionable and source materials by the Atomic Energy Commission can not be continued under an industrial licensing program. AEC inspection of all production facilities on a regular basis, will insure that source and fissionable material accountability is properly adhered to, that proper health and safety precautions are being observed and that security, where necessary, is being observed. In this manner, the AEC will have the necessary guarantees that source and fissionable materials are being properly produced and employed. The licensing program, which would require as a pre-requisite, the maintenance of strict accountability, safety, and (where necessary) security measures, can adequately control the program."—from remarks of Stanley B. Roboff, Manager of Industrial Coordination, Atomic Energy Division, Sylvania Electric Products, Inc., before the National Industrial Conference Board, New York City, New York, October 17, 1952.

"I do not think that a license to operate a plant facility would be as attractive as ownership. I believe that ownership permits you to operate a plant using the best of your experience and judgment, whereas, a license might have you so hedged in, under certain requirements, that you would be handicapped in carrying out a real free enterprise activity. Naturally, there may be certain aspects that would require you to turn over all of your fissionable material to the government, to buy all of the raw materials needed from the government, and certainly to keep within security limits. From there on it seems to me that you ought to give full range to the background of experience which has brought this country to an industrial development which is superior to that of any other in the world. * * *"—from statement of Walker L. Cisler, President, Detroit-Edison Company, before Discussion Panel, Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

3. Other Legal-Policy Questions

The proper scope and use of secrecy; the exercise of judgment in health and safety measures; how to handle the patent problem; labor relations; state regulation of utilities—these are some of the additional issues which have been publicly discussed, as illustrated in the following comments:

"I am reminded that after World War I, the Navy of the United States insisted that the national security required that wireless should stay in public ownership, that the development of wireless and therefore of the electronics industry should be wholly a matter dominated by military security. This, of course, was a lot of nonsense. Our military security would have been weakened if the Navy position had prevailed. Certainly the electronics industry would not be what it is today had that prevailed.

"Without saying that this case is a perfect analogy, it certainly throws some light on the hypnosis into which we fall about military security in this very important industrial field of the peaceful atom.

"My own suggestion is essentially this: that we apply to the atomic energy field the same security standards, one might say the same standards for security, as are applied by the military services with respect to other arms research, production and development; that we abandon as to the atom this very special dogmatic and I think excessive and self-defeating policy that is provided in the McMahon law as it stands."—from remarks of David E. Lilienthal, former Chairman, Atomic Energy Commission, before the National Industrial Conference Board, New York City, New York, October 27, 1952.

"No responsible person complains about the security restrictions and the other special conditions with which, for good reasons of national policy, our government has had to surround the atomic energy program. But, notwithstanding these difficulties which stand in the way, we need to find means of continuing the healthy conditions which have heretofore existed in my industry and which have been indispensable to technological progress. At least, if we cannot preserve in this new field exactly those conditions which fostered our progress in the past, we need to find adequate substitutes."—from remarks of Philip Sporn, President, American Gas and Electric Company before the National Industrial Conference Board, New York City, New York, October 27, 1952.

"Another problem is the need to protect industry's inventions and other original ideas developed during the course of the plutonium-power program. Admittedly, patents and inventions dealing solely with the utilization of atomic energy for military purposes should remain the exclusive property of the government. However, in order to give maximum encouragement to industrial development of atomic power reactors, there should be a modification in the present policy which forbids the granting of patents for any invention or discovery which is useful solely in the production of fissionable material. While it is understandable that such a rule be adopted during times when almost all inventions were obtained at government expense, it seems that with the approaching possibility of major industrial programs in the field of atomic power, a review of such policy is in order. For example, should not there be some right to the protection of its inventions granted to a company which, has at its own expense and effort, done further research and deveopment work to apply atomic reactors as direct tools and aids for use in the chemical manufacturing industry?"—from remarks of Edwin J. Putzell, Jr., Secretary, Monsanto Chemical Company, before Discussion Panel, Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

"Any review of the operation of the Atomic Energy Act with reference to the patent question discloses little evidence that the legislation has had any perceptible impact upon the patent system, and that in fact the patent problem in atomic energy policy, large as it is, has been greatly exaggerated and extravagantly publicized. The Commission has remained sensitive to the apprehension expressed in the debates about the legislation and in the selection of its advisors, and the Patent Compensation Board has indicated its eagerness to insure that the patent policy of the industrial community be respected to the full extent of its compatibility with the legislation. Thus far evidences of incompatibility are largely vocal and no acceptable demonstration of the gross unsuitability of the legislation has been made. This, however, does not dispose of the problem of reconciling governmental atomic energy policy with the patent policy which will insure the most rewarding employment of atomic energy for the nation."—from remarks of Casper W. Ooms, Chairman, Patent Compensation Board, Atomic Energy Commission before Discussion Panel of the Michigan Memorial-Phoenix Project Conference, Ann Arbor, Michigan, June 27, 1952.

"The operating hazards to which I refer are those risks of physical harm which are customarily protected by public liability and property damage insurance. In this new field where private industry will own and operate a plant to produce fissionable material as well as power, it will be necessary to explore the possibilities of obtaining adequate insurance protection, to

provide for self-insurance, or to devise a combination of both. If the magnitude of the risk is such as to make these customary practices impractical or too costly, other means must be developed.

"A related element of risk with its attendant legal questions has to do with the inevitable waste disposal problems of reactor operation. Radioactive refuse must be concentrated and disposed of both economically and without hazard to the environment. * * *

"The next point is the application of the Labor Management Relations Act to such a situation. How would it affect the operation of the plant containing highly radioactive materials which require experienced, skilled handling? One cannot walk out on a reactor without making sure that all precautions in the community's health and safety have been taken * * *."—from remarks of Edwin J. Putzell, Jr., Secretary, Monsanto Chemical Company, before the National Industrial Conference Board, New York City, New York, October 27, 1952.

4. Is the Present Law Delaying Atomic Power?

No individual or group, official or private, has recommended to the Joint Committee on Atomic Energy any specific amendment to the present law for purposes of assisting the development of atomic power. On the other hand, there are repeated suggestions in speeches and articles that amendments of one kind or another might be desirable or worthy of consideration.

"[Our] plan requires no legislative changes at either the national or the local level."—from remarks of Mr. Murray Joslin, speaking for the Commonwealth Edison and Public Service companies, before the National Industrial Conference Board, New York City, New York, October 17, 1952.

"What is important is to first get the law changed. You cannot have any commercial power with the existing law, as it now exists, in my opinion. It doesn't have to be changed radically, but there has to be some changes in detail on the law."—from statement of Dr. Charles Allen Thomas, President, Monsanto Chemical Company, at Chicago University Conference, December 2, 1952.

"I therefore propose that the basic provisions and fundamental assumptions of the Atomic Energy Act and its administration be thoroughly reexamined by the country. This reexamination should take into account how the law has actually worked in practice, and whether the structure of organization provided by the law tends to defeat the purpose of the act itself; it should take into account such new facts as the Russian atomic achievements. I believe this reexamination will demonstrate that a thoroughgoing revision of the law is required. I urge that the revised law state flatly and without equivocation, as fundamental policy of this country, that development of the industrial atom shall be in accord with the American system. A series of steps should be provided to achieve that purpose over the very shortest practical space of time."—from "Free the Atom," by David E. Lilienthal, Former Chairman of the Atomic Energy Commission in Collier's National Weekly, June 17, 1950.

Part II

ATOMIC POWER DEVELOPMENT SURVEY

An informal opinion survey was conducted among company executives, Government officials, scientists, lawyers, and others during September, October, and November 1952. The object was to obtain comments and views about problems involved in atomic power development. The survey was predicated on the following assumptions:

1. Atomic power is technically feasible but of unknown economic interest;
2. It is important to explore fully the desirability of utilizing atomic energy for generation of electricity in the foreseeable future;
3. The present rate of progress in this field suggests that some undetermined factors in the existing policy, managerial, legal, economic, and defense situation tend to prevent aggressive development.

At the opening of each conversation an effort was made to assure each individual of the informal character of the meeting and of the intention to avoid later direct attribution of particular comment to a particular individual for any purpose except as it would clearly conform with his own desires. No extensive notes were taken during any interview.

Thirty-six discussions were held with eighty-two individuals representing thirty-six private organizations and the Federal Government. As regards individuals employed by established companies with readily identifiable interests in atomic power development, the principal executive officer was almost always among those participating in the conversations.

1. What Is Meant by Atomic Power?

Before any discussion could get under way, it was invariably necessary to clarify definitional problems. The term "atomic power" means to each individual for the most part only that in which he can visualize himself or his own organization playing some role. In all cases atomic power meant harnessing and exploiting the heat produced in a controlled chain reaction. (No one, however, was seriously contemplating direct utilization of energy for electricity without generating machinery, although many of those interviewed spoke of this as a dream unencouraged by present scientific knowledge.) Emphasis was frequently placed on the fact that current discussion has to do solely with the heat source portion of a power plant—the "boiler" alone. The heat exchangers, generators, and distribution systems are expected to remain in conventional form, although such equipment as required for an atomic power plant will differ somewhat from that required for power plants now in use.

Two Viewpoints

The individuals separated into groups when relating the term "atomic power" to a particular sort of physical plant. One group tends to regard any plant capable of producing power to turn a propeller or drive a generator as a successful atomic power plant. The other group insists that no system should be designated as an atomic power plant unless it not merely produces electricity but also produces at a cost competitive with the electricity generated by a conventionally-fueled central power station. To illustrate, the first group regards atomic power in a submarine as economic atomic power, treating the specialized character of the application and the fact it has nothing to do with commercial electricity as only a minor distinction. The second group regards nothing less than a 150,000-kilowatt central power station furnishing power at 5 to 8 mills per kilowatt-hour as worthy of the designation "atomic power plant."

This difference of viewpoint in the very definition of "atomic power" seems to follow from different alinements of interest. Many equipment manufacturers or would-be equipment manufacturers, for example, are anxious to get on with making profitable products instead of operating present atomic plants on low-fee Government contracts; and therefore they appear eager to build the special-purpose, high-power-cost units technically feasible today. Some scientists, despite a reputation for being "perfectionists" who hesitate to "freeze design" and actually construct a facility, share the same eagerness because in this case they are beginning to resent criticism from lay quarters about failure to have evolved tangible power plants in the 7 years since the war.

Two Types of Reactor Systems

Throughout the interviews it was also necessary to relate specific observations to a specific type of reactor system, which usually falls into one of two categories:

1. Dual-purpose systems capable of producing both power and fissionable material;

2. Power-only systems producing no other presently useful product.

The dual-purpose systems include some which yield weapon-grade fissionable material and others yielding material useful only as fuel. The power-only systems include units which burn pure fissionable material and others which manufacture their own fissionable material as they operate (so-called breeders and high-burnup systems). The simplest difference between the two categories, however, is that one depends on a military requirement for fissionable material for its economic justification and the other does not.

These distinctions in definition seem partly responsible for the confusion in reactions to the reports of the four groups of private companies which completed studies last summer, in cooperation with the Atomic Energy Commission, concerning feasibility of private atomic power plants. All four groups included at least one utility company for whom "atomic power" means primarily power competitive with conventional fuels in a large electric system. None of these studies found any reactor approach technically feasible by that definition today without some kind of Federal assistance or simultaneous manufacture of a valuable product such as plutonium in addition to power.

The simple solution, it was often suggested, is sale of plutonium to the Government at a price adequate to insure a competitive power cost. This, in the opinion of all who commented, is not a subsidy if there is a Government demand sufficient to warrant the price which must be received in order to make the power generated competitive. It presumably becomes a subsidy when the demand drops or the price exceeds the military worth of the product. While most of those interviewed seemed to believe that the actual expenses in dual-purpose systems could be separated and the portion attributable to plutonium on the one hand and to power on the other calculated with reasonable accuracy, there was general agreement that possibilities of a product in addition to power is the most likely source of confusion about power costs.

2. Who Is Responsible for Development and Why?

It is not absolutely certain as yet whether generation of atomic power in any form will prove of real value in the United States within the foreseeable future. Until a series of demonstrations of utilization of power are a reality, there is a natural tendency for each interested private group to assume only enough of the developmental responsibility to insure a role in any subsequent profitable applications. This highly limited willingness to take on development responsibility is limited further by certain legal, fiscal, and other factors to be discussed below.

Government Responsibility

Some individuals in each industrial and professional group volunteered comment upon what they described as the responsibility of the Atomic Energy Commission to carry development through either pilot plant or prototype plant stages. Their position was that the AEC has a minimum responsibility to delineate a development policy, that is, at least to announce promptly and fully what it plans to do, what others will be allowed to do, and what assistance it will give to any private organization which undertakes some form of development. Some of those associated with equipment and utility companies went further and stated that the Atomic Energy Act requires the AEC to carry the full developmental load.

All discussion was conditioned by recognition that the Government has a clear responsibility to meet the military requirements for weapons and that these requirements take overriding priority. Commenting on a recent speech by Commission Chairman Gordon Dean, several businessmen expressed a belief that there is a finite military need which can be met in the foreseeable future. Most scientists and the military men interviewed tended to regard actual requirements as being beyond the limits of the calculations of the men now trying to envisage them. All participants agreed that Government is responsible for insuring adequate military supplies of fissionable material and for taking whatever steps are necessary—even to the point of delaying power development if need be—in order to avoid placing these supplies in jeopardy.

Having assumed for the sake of discussion that the AEC has responsibility for development through prototype plants, Commission spokesmen pointed particularly to the problem of selecting companies and groups to serve as Federal instruments to perform the actual

work. They noted that if the AEC itself undertook the development through direct Government operations, it would be subject to serious criticism for not "strengthening free competition," an objective set forth in the preamble of the Atomic Energy Act of 1946. There is a feeling among private groups that direct Government operations may well be more expensive because of a tendency to overinsure against failure—a tendency which is feared to be inherent in bureaucratic functioning. The possibility that such a method of development would lead to extension of the Government monopoly was also cited, along with statements that this might be contrary to the public interest as laid down in the organic act.

While the contract method of development apparently is preferable to the AEC, there is concern over how to avoid giving undue advantage to selected companies. Selection is considered inevitable because the AEC must assure itself of the competence of the contractor. This, AEC officials fear, might mean that only industrial firms previously successful in related fields of endeavor would be considered acceptable as development contractors.

One utility executive observed that the drive in Government to "take over the power industry" has run its course and is now more vocal than powerful. Two non-Government participants in this survey who have had occasion to deal extensively with the AEC volunteered observations that the Commission seems genuinely anxious to avoid the complications it would experience through assuming sole responsibility for development. The inherent limitations of any management group were mentioned in several discussions as powerful factors militating toward placement of at least part of the development task outside Government.

Attitude of the Utilities

There is some division of opinion on the matter of who should bear the development expense. One group of utility executives believed that industry should shoulder the responsibility within the meaning of the term "strengthening free competition" only if the cost of development should appear to be a reasonable percentage of the gross business involved. The term "reasonable" seemed to mean $10,000,000 to $15,000,000. "Unreasonable" meant $100,000,000 to $500,000,000.

Two utility groups felt that their industry failed to meet its responsibility in hydro development (such as TVA) and had paid a high price for that failure. They placed atomic power development in the same category, but stressed that the size of the job both in terms of money requirements and other resources is beyond the capability of any single company. They are therefore currently attempting to develop new types of utility company groups, harmonious with the policies of the Securities and Exchange Commission and the Justice Department, which can undertake a larger share of development without placing an undue burden upon any single company. They regard these as relatively long-term efforts—one to two decades.

The utility industry as a whole apparently believes it has an aggressive responsibility to develop atomic power with the dual motives of profit and self-defense—that is, defense of its own future role in the economy. The profit motive was described by several utility groups as at best indirect because little or no increased profits can

go to the investors under existing regulation but instead must largely be passed on to consumers through rate reduction. There was, at the same time, substantial concern about the rising cost of conventional fuels and the diminishing savings achievable through improved conventional fuel-handling techniques. Atomic power development is placed in a similar category by most utility men to such other lines of development as pipeline transmission of coal, gasification of coal in the ground, and extraction of oil from shales. References were frequently made to the role which the Department of the Interior has assumed in these last-mentioned areas of endeavor.

Equipment Manufacturers and Chemical Firms

The responsibility which is felt by utility men, however, relates primarily to central station atomic power plants which would follow the pattern of the existing power systems. The equipment manufacturers and chemical firms are concerned not only with fixing responsibility for central station plants but even more for development of the "specialized" applications. These groups indicated that they believe the military and the AEC have already assumed development responsibility for these "specialized" atomic power uses. They cited the existing AEC projects based on military requirements for submarines, aircraft carriers, and aircraft. They referred to additional studies now going forward such as those envisaging remote military stations, unattended monitoring stations, and other more dramatic objectives.

Without exception not only the equipment manufacturers but chemical companies as well indicated a willingness to assume responsibility for providing the management and manpower to carry out these "specialized" atomic power applications. They asserted that most companies are able to place a precise dollar value, in terms of income to stockholders, upon the services of management and manpower—a dollar value which, they said, is by no means inconsiderable.

While it is clear that some individuals in the equipment manufacturing industry personally found the prospects of atomic power challenging and exciting, the basic motivation is of course the desire to sell a useful product for stockholder profit. The companies in this field are concerned with protecting their position in the power industry. If that industry changes in character, they are anxious to be in the forefront of the change. The generating equipment manufacturers pointed out that their largest returns come, not from the sale of generating equipment, but from the sale of power-consuming devices. Their aim therefore is to keep the power consumption rate rising. To the extent that atomic power will abet this rise, they see its development as figuring naturally in their over-all responsibility to their investors.

There are also some groups which see in atomic power development an opportunity to compete with the existing power equipment manufacturers for the first time. These groups appear to be motivated by a desire to expand the scope of their activities in order to improve their economic stability, as well as to seek additional profits. Companies heavily dependent on military products are predominant in this category.

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Role of the Chemical Industry

No one felt that the chemical industry (including oil companies) has any central responsibility for atomic power development. If there is any prospect of manufacturing fissionable material for sale to the Government or of developing extensive uses of fission products, however, the chemical groups are definitely interested. The bluntest characterization of this attitude was furnished by a utility company executive, who indicated that chemical companies expressing interest in atomic power development are camouflaging a desire to get into the fissionable material production business—with the Government as an exclusive customer which could be easily pressured into an infinite procurement program similar to Federal purchases of silver. One chemical company executive, indeed, made plain that his company is more interested in producing plutonium than power if there came a choice between the two; and another chemical company executive has expressed a similar view. This latter individual also commented at length on the potential value of byproducts gained from reactor operation and the similarity of this opportunity to the lines along which the chemical industry has grown and prospered in the past.

By contrast, at least two chemical companies were mentioned (by persons outside this field) that consider themselves as potential atomic plant operators producing power only (no plutonium) on a profitable basis and that are currently in the atomic energy program in part to seek experience for such a role. These two companies are described as reasoning that the power plants should be built and owned by Government and that their own assignment as operators should be on a contract basis.

Patriotism as Incentive

The patriotic motive was always mentioned by those interviewed. In several cases the challenge to develop atomic power was categorized as a challenge to western civilization rather than to the United States. This distinction seemed to be an important one because comparatively few individuals stated that the United States must achieve atomic power first. Despite frequent acknowledgment of the American character trait of liking to be first in everything, there appeared to be serious depreciation of the concept of developing atomic power just for its own sake. Most participants related the cost of atomic power to its economic worth. They invited attention to the fact that many areas in the world now have electric power only at prices substantially above those in the United States. Some comments were made to the effect that the United States bears a leadership responsibility to assist these countries in developing atomic power under the point 4 program. This view was emphasized by reference to the extensive American assistance currently required by many of these countries because of their inability to obtain adequate low-cost power from conventional sources. To the extent that the cost of these assistance programs to our taxpayers could be reduced ultimately, an economy motive in adding atomic power development to the Point 4 Program was suggested.

Statements were made by several scientists and others along the line that an overly pessimistic view of the fuel outlook is in vogue. These individuals argued that the forecasts of energy requirements are far too high and that existing fuel sources will be adequate for a

long enough period in the world as a whole to permit a more gradual development of atomic power than was contemplated by the four study groups which reported last summer to the Atomic Energy Commission.

3. Why Is There No Atomic Power Plant in Existence or Under Construction Today?

Many of the scientists and company executives, as well as Government officials, summarized what has been done thus far to develop atomic power plants in the apparent belief that a historical review might help explain why no such plants are as yet in existence or even under construction. A high percentage of the individuals and companies contacted in this survey have been active in the atomic power field since 1945. Some participated in the work of the Power Pile Division at Oak Ridge during 1945 and 1946. That project had as its purpose an early demonstration of electric power production on a commercial scale, even if not at a commercially competitive price. There evidently proved to be inadequate scientific and engineering data in existence to solve critical problems relating to heat transfer, metallurgy, fuel handling, and the like. Those who took part returned to their companies or remained in Government laboratories but often, in one way or another, contributed to the continuing efforts to acquire the knowledge that seemed essential for greater success.

Others referred to the past focusing of atomic power hopes upon the power-breeder project under way during 1947, 1948, and 1949 in the AEC-owned Knolls Atomic Power Laboratory near Schenectady, N. Y. This project, before it was terminated in spring 1950, was aimed at achieving breeding and power simultaneously. Power would have been produced in far more than token amounts; and some of the informants said that there was talk of feeding this power into the New England electric power grid (parts of New England being a high-power-cost area).

As the work proceeded, the original concept of a power-breeder unit operating with intermediate speed neutrons encountered increasing difficulties. Particularly for cost reasons but for other reasons also, it was recalled, the AEC decided to redirect the project toward construction of an improved submarine propulsion plant, as to which economic considerations would loom less large. Many of the persons interviewed spoke of the widespread regret that accompanied this shift to a military end product—despite the fact that the improved submarine reactor (a prototype of which is today under construction near Schenectady) would contribute materially to ultimate development of an atomic power plant for industrial purposes. Some noted that if the power-breeder reactor had not been discontinued in 1950 but instead had been constructed as originally planned, the AEC would by now face a situation in which it would have to decide what should be done with significant quantities of nuclear-produced power. It was also noted that this reactor, had it become a reality, might have made available some of the cost data needed for competitive cost studies.

Many individuals in both industry and Government foresaw dual-purpose atomic power plants (producing both power and plutonium) as furnishing the most likely and practical transition from the

plutonium-only plants of the present to power-only plants of the future. Such a transitional program, these individuals stressed, might provide necessary financial support for high development costs involved in atomic power facilities. The high costs were largely attributed to the necessity of conducting lengthy empirical experimental programs, plus the necessity for relatively large-scale pilot plants to "prove in" experimental data. One Government official estimated that atomic pilot plants will cost 20 percent of the full-scale plants, in contrast to the 10-percent figure experienced in most industries. Since the first full-scale plants might cost from $50,000,000 upward, even the pilot-plant costs are widely thought to be beyond the reach of private industry unless plutonium is also produced and sold to the Government.

4. Who Should Own Atomic Power Plants and Development Facilities and Why?

The consensus was that the ownership problem falls into two parts:

(*a*) The reactor and fissionable material.

(*b*) The power generating equipment.

The present law forbids private ownership of reactors and fissionable material. In the future, it would seem, the alternatives seriously to be considered for ownership of reactors, fissionable material, and facilities handling fissionable material are: Exclusive Government ownership; permissive licensed private ownership; or required exclusive private ownership subject to Government regulation. No one has suggested that Government own the power-generating equipment. Everyone seemed agreed that the group desiring to generate the power should finance and own the equipment to do so. Most individuals recommend that the owner of the generating equipment also be the operator of the reactor as a minimum, regardless of whether this owner is a utility company, a military user, or a special group organized to undertake the project. There was also wide agreement that, as to prototype plants, legal ownership is less important than control through management and that the AEC could appropriately finance and own at least the heat-producing portion of the system.

Laboratories

Current development work is being conducted almost entirely in Government-owned laboratories; and these include the so-called "national laboratories" at Brookhaven, the Argonne, and Oak Ridge, as well as the so-called "applied laboratories" such as those at Schenectady and Pittsburgh. Most individuals surveyed from all professions and industries regarded this approach as sound, provided that competent interested individuals may obtain access to data developed in the various laboratories. The necessity of maintaining facilities for fundamental research to support the military program was frequently cited as sufficient reason for indefinite extension of the "national laboratory" program. One individual with an engineering background, however, was sharply critical of the "national laboratories" on the ground that they tend to undertake applied development work which could be carried forward more aggressively and more efficiently in competitive privately-owned applied laboratories.

The existing Government-owned "applied laboratories" were generally expected to be bought out eventually by private companies. Most individuals not associated with companies considered likely someday to become the owners thought these "applied laboratories" should be sold to private firms as soon as consistent with military needs. Individuals employed by companies deemed likely to be the eventual owners also believed that the facilities should be privately owned—but not until a firm market has been established for the sort of products they are now seeking to develop. In other words, it was felt that "applied laboratories" occupied with military propulsion plants should remain AEC-owned until they have completed prototypes. In the case of "applied laboratories" working on naval systems, this development time span was thought to be about 5 years; in other cases, the delay in private purchase was expected to be longer. Clarification of the patent situation was thought necessary before the purchases could be consummated. All interviewees seemed to believe that the operating contractors of these "applied laboratories" should have an automatic option or first refusal on the facilities and that there would be no conflict with the public interest in such an arrangement.

Fissionable Material

The Atomic Energy Act of 1946 precludes private ownership of fissionable material, but the problem of who should own it arose in every discussion. The arguments put forth for continued Government ownership made reference to the primary weapon value of the material and the continued existence of the United States international control plan before the United Nations (a plan which may preclude private ownership).

The arguments against Government ownership were heard more often. However, these arguments seemed directed far less at the legal concept of Government ownership than at consequences which might but need not inevitably follow from that concept. In other words, all individuals who voiced the arguments in question indicated they might be satisfied with continued Government ownership provided that it were exercised so as not to fetter or handicap future private endeavors.

There was a widespread belief that non-Government investment in atomic power will never be possible unless the private group concerned may control the fuel to operate the plant. Suggestions were made that some form of guaranty might be given by the Government agency or by law which would furnish private investors at least as much assurance of availability of fissionable material as investors enjoy today with regard to conventional fuels.

Moreover, the technical difficulty and consequent cost of accounting for fissionable material was thought by some to be so complex as to preclude any foolproof Government leasing or loaning system. Since fissionable material is not only consumed, but at least in some quantity is also simultaneously produced in most prospective systems, it would be expensive—"prohibitively expensive," in the words of several persons interviewed—to know at a given time exactly how much such material any plant actually had in its possession. Most individuals who explored this predicament concluded that the question of who owns the material is largely irrelevant so long as there exists legal or contractural assurance that all parties involved are operating in good

faith—and that if such were not to be the case, private plant operators should not enter the atomic power business.

One individual speculated that the coal and oil industries would not have attained the current level of progress if these fuels had been solely Government-owned. An alleged delay in tideland oil development was cited as a sample of the "snarl" such a Government-dominated situation might engender. The same individual speculated, incidentally, that ways might be found of getting more domestic uranium from the ground if the companies interested in power development saw hope of enjoying control over the ores. Such additional raw uranium over that now available would in no way detract from ore necessary for the weapons program, he pointed out, if this program is in fact now firm—which he doubts.

Fuel Preparation and Processing Plants

The ownership of plants for preparing fuel to be *inserted* in atomic power plants tended to be discussed in conjunction with ownership of plants for processing and recovering fissionable material from fuel *discharged* from the plants despite radical differences in the nature of the two operations.

There were three broad sets of commentary on fuel preparation and processing plant ownership. First, if the Government retains ownership of all fissionable material, it should also own all plants which handle the material or in any way change its character. This was essentially the view of the scientists. Second, the only way to reduce the high costs of fuel preparation and processing was thought to consist in providing strong profit incentives either by private plant ownership or by unit-price operating contracts for Government-owned plants. This view was most prevalent among the chemical, oil, and equipment manufacturing company executives. Utility executives stressed a third point, namely, that ownership of such facilities is of little or no concern to them just so long as some organization other than their own companies builds and operates the needed fuel preparation and processing plants. The utility people evidently believe that they will have, as some of them put it, "all they can handle" in the atomic power plants proper.

Threaded through all commentary was concern over providing strong incentives for reducing costs of fuel preparation and processing. It was generally agreed that, under direct Government operation or under fixed-fee contract operation, the emphasis tends to be placed upon maximum product recovery, safety, and security. While no one suggested that these aspects should not be treated with care, many indicated that costs could be lowered substantially if there were more incentive to do so. Thus the administrative method of operating the fuel preparation and processing plants was clearly of more interest than the question of ownership over such facilities because of the direct bearing this phase is expected to have on the over-all economics of atomic power. The lower the fuel cost and the lower the processing cost, it was repeatedly said, the greater the likelihood of achieving atomic power competitive in the United States with conventional fuels.

Reactors

Most persons interviewed felt that Government should own all experimental reactors regardless of the particular power application.

This concept seemed to apply to central power station prototypes as well as to prototypes designed for special power needs such as in remote locations. There was agreement on the desirability of ultimate private ownership wherever possible.

The arguments for Government ownership of prototypes centered on the size of the risk and liability involved. Utility executives stated that they cannot obtain capital for risk ventures running into tens of millions of dollars. They generally spoke of the reactor portion of a central power station as costing $40,000,000 and the non-reactor portion an additional $20,000,000 to $40,000,000. A few individuals expect the costs to run both lower and higher than these figures. Over and above the cost argument, there were references to the possibility of war intervening in the course of the development period; heavy demands for private risk capital to be used in conventional channels; prohibition of private ownership of reactors in the Atomic Energy Act; and the probable high rate of obsolescence among early atomic power plants.

Some individuals spoke not only against private ownership of prototypes but even against private ownership of reactors following afterward. Their arguments had to do with the extent of the liability in the event of a "pile melt-down"; the inevitable uncertainty over availability of fuel; and conflict betwen public and private interests. The same individuals expected that Government-owned reactors could sell heat output to private consumers as visualized in the Atomic Energy Act and thus avoid most of these problems. In answer to questions about the size of the Federal investment this would entail, a frequent reply was that it makes comparatively little difference who finances the plants so long as the public derives the eventual benefits.

The point to which most participants returned again and again is that whatever the legal ownership of reactors, an atomic power system as a whole can be run economically and efficiently only under the direction of a single operator.

Power Generation and Distribution

Distinctions between the reactor, the heat exchangers, the power generating machinery, and the power distribution equipment are related almost entirely to the concept of central atomic power stations. If such plant complexes are built, the utility industry hopes to develop, finance, and own all portions except the reactors themselves. Industry executives believe this is permissible under the Atomic Energy Act of 1946 and picture their companies as operating the reactors under contract and purchasing the heat. This is regarded as the minimal workable arrangement not only for reactor prototypes but for ultimate production models as well. In the case of the prototypes, however, there exist a series of current proposals which in effect call for the AEC to insure the utility companies against unprofitable investments in associated equipment in the event that the prototype reactors themselves should fail.

There were two separate situations described involving joint private-Government ownership. In both situations it is assumed that the Government builds and owns the reactor while a private group builds and owns the heat exchangers, generators, and other apparatus. In the first situation successful reactor operation is assumed, in which case no Government payment to the private group is anticipated.

Instead, the private group buys the heat from the Government-owned reactor much as it might pay a price for using the water flowing over a Government-owned dam. The second situation assumes a failure or shut-down of the Government-owned reactor for either technical reasons or altered military circumstances. In this case, it is anticipated that the Government would be obligated to pay the private group sufficient funds to replace the special parts of the heat exchanger and generator system so as to permit use of the privately financed part of the plant in conjunction with a conventionally fueled and not a nuclear heat source. Thus the Federal liability which is contemplated is contingent upon failure or shut-down of the Government-built and Government-owned reactor.

Private ownership of the power-generating and distribution systems probably imposes a further condition: The atomic power prototype reactors must be built on private utility sites within workable distance of the company-owned and operated conventional power grid, in the opinion of most utility executives.

Several individuals associated with equipment-manufacturing companies commented that split ownership of industrial power facilities might be analogous to split ownership in the military field, where the consumer of the power is now planning to own the generating and distribution facilities but not necessarily the heat source. This reference was to the Navy, which may own only the nonreactor portions of submarine and carrier systems, and to the Air Force, which may own only the nonreactor portions of aircraft systems. However anomalously, the Atomic Energy Commission under the provisions of the law may retain legal title to the fissionable material and the reactor in a submarine, carrier, or aircraft.

5. How Should Atomic Power Development Be Financed?

This problem was usually approached in two parts: Study and experiments on the one hand and pilot or prototype construction on the other.

Private Financing

Financing of power-development studies was undertaken in 1951 by the four groups of private companies mentioned above. Actually, as many of those canvassed took pains to note, a number of private companies have been making a management and professional investment in atomic power studies for the Government since 1945. But it was often observed that development on a substantial scale requires far larger investments than has been true in any of these past instances. A paper study may be feasible for $100,000 to $200,000 spread over 1 year or more. Most groups regard this as a token of interest, not a financial investment. A full development program, in the opinion of most of the interviewees, would entail an expenditure of at least a few hundred thousand dollars per year for several years, plus the help of basic research support of national laboratories. This would be followed by an outlay of at least $15,000,000 for a pilot plant, or $60,000,000 or more for a prototype.

Another frequent observation was that all four of the industrial atomic power studies completed in mid-1952 (and to which many of those interviewed have had access) indicate that the sooner a private

effort were made to build an atomic power plant prototype, the more extensive would have to be the contribution by the Government laboratories in terms of carrying out additional research and experiments. No one seriously suggested that the basic reactor art is sufficiently advanced to enable a private group to design and build an atomic power prototype simply by gaining full access to existing data as thus far developed by the Atomic Energy Commission. Several individuals stated that they are thinking hard, however, about possible means of avoiding Government financing and are exploring new corporate devices, nonprofit foundations, industrial associations, and other organizational means toward this end.

Government Financing

Some scientists said they believe that Federal financing all the way through to a central station prototype is the only expeditious approach available. They also suspected that this might prove to be a more expensive approach than one involving private money because "the AEC can't afford to fail." Their view was amplified by an engineer who observed that a successful power prototype must involve greater "technical gambles" than the Government might feel it can afford to take. He feared that any AEC-financed development would sacrifice daring for sureness of accomplishment, would therefore produce high-cost power, and might even on balance retard rather than stimulate further development.

A direct comment on Government financing was offered by one executive who indicated that, as long as there is any expectation that the AEC may finance both studies and pilot or prototype plants, private companies will find other uses for their risk capital. Another executive made a similar statement and explained it on the ground that the risk is too high for the size of the investment, not to mention the "tremendous tax bite" which the Government would take in any ultimate profit.

Tax Advantages and Subsidies

In most interviews there was discussion as to the use of tax advantages to encourage private financial development. Permission, for instance, to amortize facilities and prototypes over a short period of years was mentioned as possibly providing incentive if there were confidence in ultimate profitability of the plant. (Utility executives did not hesitate to say that the excess profits tax situation has encouraged chemical and oil companies to spend money on atomic power studies utilizing funds which would otherwise be paid in taxes, whereas a like option has not been open to the utility companies.)

The most commonly discussed special incentive involves guaranteed AEC purchase of plutonium at an established price for a minimum span of years. The period of time and the price were usually defined as adequate to insure full recovery of all investment, minus an allowance for the going market value of the power produced. This concept applies only to dual-purpose reactor systems. It permits competitively priced power by what was sometimes termed "TVA accounting."

AEC public statements which appeared while this survey was being conducted suggested that the military demand for plutonium may be met "in the foreseeable future." These statements were of keen interest to those who had been responsible for some of the optimistic

public forecasts about atomic power issued earlier in 1952. Spokesmen for one chemical group indicated that these new AEC statements must be taken as reflecting a startling reversal of policy and that, if the statements turned out to be well founded, their group would have no further immediate interest in atomic power.

Another group estimated that the value of fissionable material for use as fuel in power-only reactor systems eventually will at least equal its production cost in such dual-purpose reactor systems as can be built in another 5 to 10 years, and in this case the existence of a military customer would be of far less significance. The same group stressed that Government purchase of fissionable material is not a "subsidy" if the material is actually needed to meet military requirements and is worth the price paid in terms of the cost of military devices which would be necessary if the fissionable material were not available.

None of the individuals supposed that free access to AEC-financed scientific and engineering data, plus free use of AEC-owned fissionable material, would be an adequate financial-assistance program. Some engineering and cost estimates were produced to demonstrate that atomic power alone from central power stations is not economically competitive today even if the fissionable material is furnished beforehand and processed after use free of charge. On the other hand, a complete reverse of the above "proof" was offered by others to show that a price 10 times higher than is currently being paid by the Government for fissionable material still would not preclude eventual achievement of economically competitive electricity from central atomic stations producing power only.

In general, it appeared that as long as the construction of a prototype was assumed to be several years off, there remains hope that no Government subsidy would be needed except in the development stage. The more immediate the construction effort was assumed to be, the stronger the belief in need for Federal assistance. Most individuals associated themselves with this conclusion regardless of industry or profession.

One executive raised the possibility of devising a special Government incentive loan scheme to encourage private industry to build prototype atomic power plants. The specific idea suggested was patterned after the current proposal for stimulating development of commercial jet airlines. This idea in the aircraft field involves a Government loan at a low interest rate, which must be amortized at a fixed rate but which can be written off rapidly by actual delivery of jet airliners to commercial services. It was not clear that the United States has a sufficient near-term demand for atomic power to warrant adoption of such a suggestion, in the opinion of most other persons with whom the idea was discussed. They nevertheless commended it as a potentially useful device later if development by different means should fail.

6. What Is the Public Interest in Atomic Power Development?

Public money has been used to finance all atomic power development to date. As a result, almost every interview touched upon some aspect of the public interest in development. Government officials tended to fear that any private profits made by applying data acquired at public

expense might be subject to political attack as industrial participation in the United States Treasury instead of in atomic power. Some industry spokesmen were inclined to favor slower development, more public education, and multiple joint private-Government development projects to offset what were in several instances described as "emotional" misunderstandings of the public-private relationship. No one challenged the assumption in the Atomic Energy Act that commercial power developed from atomic energy should be developed and exploited within the "free-enterprise" concept so far as national security will permit. There were no suggestions that the public interest could be protected only by continued complete Government monopoly.

Many individuals with scientific or engineering backgrounds expressed trepidation over the possibility that atomic power might be used as a "power yardstick" in the same way they said that TVA power has been used. Such concern appeared to relate primarily to dual-purpose systems producing fissionable material as well as power. These individuals, in their own personal experience, had encountered problems involved in seeking to explain why power generated by private systems could not compete with power from Government systems. Their conclusion, generally, is that the public interest is not best served by concealment or adumbration of certain costs, so as to produce what they described as a misleading conclusion concerning the actual cost picture.

One of the more unusual comments come from an engineer, who believes that the existing Government investments in atomic energy tend to impede rather than stimulate development along the radical lines which he suspects must be explored if large cost reductions through atomic power are to be achieved. In other words, he seriously questioned the ultimate political feasibility of writing off, on grounds of technical obsolescence, billions of dollars of public funds invested in Government-owned plants. If these plants, however obsolete, are to continue indefinitely in operation, the incentive to substitute for them facilities of more advanced design might be reduced. The same individual also contends that the public interest is promoted by producing the greatest and cheapest possible volume of useful power, since the key to modern industrial society is the availability of ever larger blocs of energy capable of being harnessed for useful work.

Future Power Needs

The utility company executives as well as the generating-equipment manufacturers discussed the relation of atomic power to the over-all power needs of coming decades both in the United States and in other countries. They noted that the power consumption per person in countries with a high standard of living is vastly beyond that attainable for remaining countries from known conventional energy sources. The report of the President's Materials Policy Commission issued in June 1952 had attracted wide attention and was often cited to support the belief that the broad public interest will best be served by insuring maximum development of atomic power and its careful integration with military requirements for fissionable material both in the weapons and propulsion field.

The current AEC production expansion program, while not questioned in principal, was cited on several occasions as a failure of the Government management approach to atomic energy development—

in the sense that the expansion effort is not expected to involve a coordinated program for development of atomic power concurrent with increased production of fissionable material. It was usually conceded that the urgency and unforeseen nature of the unfolding military situation is a partially acceptable defense for this "missed opportunity." Some fears were expressed that the present expansion program may result in such a large public investment in fissionable material production facilities as to delay atomic power development, to the detriment of the longer term national security and public interest. Rumors that the AEC might change its plans and generate some of the power for the new Portsmouth, Ohio, gaseous diffusion plant through a Government atomic power system were generally discounted because such an approach might entail a delay in starting operation of the Portsmouth facility.

Government Regulations

The utility executives expressed confidence that regulations could be developed between State and Federal agencies to insure that both public and private interest in atomic power development can be protected. They regretted any tendency to assume that only Government ownership could adequately safeguard the public interest. As already indicated, the general reaction to questions about protecting public investment was to urge aggressive joint private-Government development and to deplore any delays engendered by hesitation to permit private exploitation of knowledge initially developed at public expense. It was pointed out that private action might produce substantial additions to this knowledge—advances that might not otherwise be realized.

7. What Are the Defense Aspects of Atomic Power Development?

The primary defense aspect of atomic power development discussed by most participants was the possibility of conflict between weapon requirements for fissionable material and power requirements. The hope of avoiding this conflict or minimizing it appeared to be a strong motivating force in the widespread interest in breeder-type reactors. These systems would theoretically be able to produce at least as much fissionable material as they consume, as a consequence of capture of excess neutrons in fertile nonfissionable material. Power-producing atomic breeder systems are considered attractive by the utility groups particularly because they would minimize any competition for fissionable material requirements.

Weapons-in-Being Versus Production Capability

There is some conflict between the philosophy of developing a stockpile of atomic weapons capable of meeting all reasonably conceivable military situations on the one hand and of having large fissionable material production capacity available to meet military needs as they arise on the other hand. Those who argued that the stockpile in being is the only important item did so on the assumption that any atomic war will be short and intense, fought essentially with weapons in existence at the beginning of the conflict, and possibly involving early destruction of the production plants. These individuals seemed to presume that military need for fissionable material can be expressed in terms of a fixed amount—so many kilograms—and that the need will not expand with advances in technology and the growth of rival-

nation stockpiles. They therefore stressed the desirability of producing the required material as rapidly as possible by the cheapest and most expeditious means and then writing off the production facilities as a defense cost. Following this, they visualize a more orderly and less costly atomic power development program.

Those who argued more for a production capability than for material in being stressed that even atomic wars cannot be compressed in time beyond the capability of the people engaged to respond and act upon the major developments ensuing in those wars. Therefore, they anticipate an immediate need for some fissionable material in weapons, followed by a more protracted need for additional fissionable material in differently designed weapons, propulsion systems, and unforeseen applications. One strong advocate of the use of radiological warfare agents emphasized that conceivably only plants in being with large production capacity could meet possible RW needs in time of war.

All of these latter arguments were used to support the contention that the best defense system could be achieved by encouraging private industry to develop, construct, and operate a considerable number of atomic power plants capable of producing large quantities of power and small quantities of fissionable material in peacetime and also capable of conversion to production of smaller quantities of power and large quantities of fissionable material in wartime. No ready answers were forthcoming as to the problem of wartime disruption of power consumers dependent on the power output of these plants except to suggest that such facilities could be limited to a predetermined maximum percentage of any particular power grid in order to reduce dislocations.

Some of the equipment-manufacturing executives and scientists spoke about possibilities of developing compact atomic power plants able to furnish the power needed to develop mineral resources in areas now too inaccessible for profitable exploitation. There was also discussed the future possibility of achieving vast cost reductions in basic metals by actually refining the ore at the mines, a step to be made possible by introducing atomic power into areas where conventional power is unavailable because of high cost fuel transportation or lack of water.

Specialized Military Uses

The significance of atomic power plants in many specialized military situations was cited as possibly supplying more than adequate incentive for development at public expense. Among the systems mentioned were: Atomic-powered naval vessels and cargo ships capable of cruising for their entire life spans without refueling; atomic-powered aircraft capable of making multiple feints preceding an actual military attack; atomic-powered floating power stations capable of meeting the power requirements of bombed-out ports and cities during wartime and disaster-stricken areas in peacetime; and atomic power plants to meet power needs of remote military bases now dependent on expensive fleets of oil tankers which would be still more expensive to convoy to and from their destinations in wartime.

Wartime Recovery of Material

One of the concerns of those who are interested most in central-station power development is the problem of rapid recoverability of

fissionable material for weapon use in the event of war. Reactor systems can be designed so as to permit speedy low-cost recovery of the fissionable material; but that material is of circumscribed utility for weapons unless the power plants have been operated in a particular manner for much of the period during which the fissionable material has been in the reactor. This is felt to impose a major impediment to any AEC requirement that all fissionable material allocated to power plants be rapidly recoverable for weapon use in an emergency. Most individuals have concluded that any power-plant allocations of material should be considered essentially irrevocable. One engineer commented that, if as much money were to be devoted to increasing uranium-ore supplies as would be required to subsidize operation of atomic-power plants in the degree necessary to guarantee continuous weapon availability of the fissionable material employed, the result would be many more weapons available concurrently with atomic power plant operation.

Plant Location

The defense aspects of atomic plant location had not been of concern to most of those interviewed, but some discussion developed on this point. Several individuals suggested that a large number of dual-purpose systems producing atomic power for industry and fissionable material for weapons would reduce the vulnerability of the United States production capability by the dispersion which would be achieved. An atomic-weapon production program drawing on plants scattered around the United States was thought to be cheaper and surer to defend against enemy strategic air or subversive attack than one dependent on a few large, heavily protected concentrations of plants. No one felt anxiety about possibilities of an enemy seizing a fissionable material and power-producing plant, on the grounds that any nation sufficiently advanced in science and technology to handle and recover the material from the atomic fuel is likely already to possess atomic weapons in substantial numbers.

8. What Is the Effect of the Patent Situation on Atomic Power Development?

All conversations with individuals employed by private companies, as well as those with some other individuals, involved discussion of the relation of patents to development. It was noted that the organic act prohibits private ownership of atomic-energy patents.

Just before the present survey was conducted, a Government official had speculated publicly on the difficulty of allowing private patentable development to be built on a foundation of Government-financed development without doing an injustice to the taxpayers. Several manufacturing executives pointed out that all patentable developments must draw upon the history of the art to which they relate as well as upon the prior skills and knowledge of the developer. Since the mechanics of the transition from public to private development seemed to be involved more than any question of inalienable public rights, they anticipated that the only real need would be for the responsible officials to sit down and work out a reasonable scheme. They decried what they termed "handwringing"; that is, excessive worrying over a problem best solved by making some sort of decision and then proceeding.

One equipment-manufacturing group stated that the patent provisions devised for nonatomic military development projects have proved satisfactory to both industry and Government. Such provisions allow the group responsible for the development to obtain patent rights to any public-financed development but reserve a royalty-free license to the Government. A like arrangement, it is believed, would give more incentive to private financing of atomic power developments than does the present patent prohibition. The same type of arrangement is anticipated as a sort of bonus which might someday be conferred upon the private contractors which have managed and provided the know-how for the atomic-energy industry to date at what these contractors believe to be below-cost fees.

Most manufacturing executives seemed to expect that a reasonable solution to the problem of insuring "equitable access" to atomic power developments lies in this combination: Restoration of private patent rights for privately financed developments; review by a joint public-private board of all patents in the "gray" area involving some public and some private development investment; more rapid declassification of technical developments as well as narrowing of security classification categories; and more rapid declassification of patents now held by AEC. All such commentary had to do with the atomic power problem. Repeated assertions were made that atomic-weapons data should remain exclusive Government property indefinitely, regardless of any private investment which might accidentally be involved.

Some executives viewed patent protection as a significant factor in any private development, while others expressed concern only as this problem covers what they called "the one really important idea" which most chemical and equipment companies are "always hoping to obtain." In general, chemical executives displayed the most interest in the patent problems; equipment manufacturers a moderate interest; and the others almost none at all.

9. What Are the Secrecy and Safety Problems in Atomic Power Development?

Every participant spoke about the problems of information security. It was consistently averred that no atomic power system could be developed either expeditiously or efficiently without the aid of presently classified information termed "restricted data" in the law. One scientist, to be sure, is currently proposing a medium-sized research reactor to be designed and built on an unclassified basis; but he himself has had access to "restricted data" for so long a time period that his colleagues pointed out he could probably no longer tell what part of his thinking is of a classified nature and what is not.

Reactor Data

The scientists all expressed the view that present AEC security policy with regard to reactor data is unrealistic. They emphasize that this AEC policy, with its severe compartmentalization, prevents rapid exploitation of new ideas; that many other countries now possess successful reactor programs of significant size; that the complexity and scope of the United States program would permit our Nation to capitalize faster on new developments than other nations and thus gain "security by achievement" rather than "security by

concealment"; and that the present policy positively hinders development of active competition by preventing the bulk of industry from knowing precisely with what it must compete.

Most persons interviewed said that the reactor art would advance faster and at less expense if the AEC could see its way clear to declassifying all pertinent data, including precise construction and production cost figures as well as information relating to fuel preparation and processing. It was generally felt, however, that military security might require that the operating details of plants producing weapon material and the specifications for that material be declassified only on a highly limited and cautious basis.

The industrial executives interviewed sometimes cited some of the above arguments, but they most frequently discussed the large additional cost of the existing information-control system to both taxpayers and industry. Estimates of the cost attributable to informational security ran even as high as 50 percent of the total for any given development project. No specific estimates of time delays occasioned by security were attempted, but many episodes were related illustrating obstacles encountered because of the present complex procedures in transmitting reactor data from one group to another. Most industrial executives mentioned the 3-month period required to obtain security clearance for employees. So-called industrial security was cited several times as adequate to protect the engineering know-how, which, according to the informants, is often the most significant information in a development program.

Personnel Security

While many participants commented on the length of time it now takes to obtain security clearance for classified work upon atomic power development, the most serious concern had to do with the basic effectiveness of the existing personnel-security system. On several occasions comments were made that the AEC is now so occupied with regulating so many people that it cannot sufficiently apply itself to checking upon the few key people who alone would be in a position to compromise extensive and vital data. The solution often proposed would consist in reducing the areas of information and physical security so as severely to reduce the number of individuals who would need clearance. One individual half-jokingly and half-seriously suggested that the Nation would in time either have to follow this course or else clear almost the whole population.

Two discussions touched on possible personnel-security approaches for private atomic power-plant development. These followed the line that an industrial group might experience more difficulty meeting its responsibility in this area and hence might have to employ even more complete control techniques than does the Government. Specifically, it was suggested that the AEC might certify all employable persons prior to their being given access to classified data entrusted to an industrial group. The industrial group, however, would pay a fixed charge per certificate to cover the cost of security investigation. In addition, there were some references to possible use of lie detectors on all employees at regular intervals, but this approach was vehemently opposed in other quarters.

Physical Security

There were no fears expressed that the physical security of atomic power plants would present any more difficult a problem than that

of other industrial plants vital to national security. A Government inspection service was suggested as a task for the AEC to perform by way of assuring acceptable measures in privately owned plants. Many industrial firms have had extensive experience with provisions for physical security during wartime. Here, too, the point was made that greater physical security could be achieved through a large number of plants widely dispersed than through a few concentrations of plants closely guarded.

Safety

One of the men partially responsible for formation of the Reactor Safeguard Committee, an AEC advisory body that reviews all reactor proposals to insure necessary safety precautions, expressed the opinion that some means must be found to provide an incentive to take greater risks—risks which, in his judgment, a nonemotional appraisal of the hazards would fully justify—in the field of atomic power plant safety. This same view was expressed in varying forms by almost every participant in the survey, but usually with the explanation that it is a personal opinion difficult for a responsible organization to defend in what was termed "an atmosphere of unreasoning supercaution."

Technical data was cited by scientists and engineers to indicate that there is public misunderstanding as to the sort of factors which are involved. Chemical executives, for instance, pointed out that hazards of running bulk-chlorine plants are at least as great as the danger from an atomic power plant. Inherent system safety was often mentioned as a real goal of some current studies. There is apparently hope that, in the near future, fear of the types of hazards against which the most elaborate safety measures have been employed can be alleviated.

Despite these hopes, however, most industrial executives were careful to bring up the problem of health and safety responsibility. There were two steps discussed as being of possible assistance in this area. First, a realistic set of regulations might be prepared by a joint industry-Government body either within or independent of the AEC. These regulations would be policed just as regulations governing other hazardous operations affecting public welfare are policed. Second, the Government might assume or retain full responsibility for the community and worker hazard against which the industry does not yet know how to guard. These steps to define the respective responsibilities of private groups and the Government were widely denominated by most persons surveyed as essential to vigorous private activity in the field of atomic power development.

10. What Effects Can Be Expected From Executive Department Actions?

The possible effects of all courses of action and inaction on the part of the various executive departments and agencies concerned and the consequent effects upon atomic power development is apparently a popular field for speculation. Some of the comments are sketched here as illustrative of those received during the discussions.

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Federal financing of one or more dual-purpose atomic power prototypes is expected, among a few, to discourage substantial efforts by private groups directed toward power-only systems, because the pattern of permanent Government monopoly of the atomic heat sources might tend to become more entrenched. A far more widely held view is that Federal financing of such prototypes would speed ultimate power-only development because of the experience that would be gained rapidly during a period when the financial risk may be too large for private companies to undertake.

Establishment of additional military requirements for specialized atomic power sources is considered a possible competitor for the manpower, facilities, and materials needed for industrial atomic-power-development projects. There were several comments to the effect that whenever a group develops a competence in reactor development, it soon receives an assignment of a military character. However, some who made this comment added that no other immediate customers for atomic power plants are on the scene to compete for the services of groups capable of developing such plants.

Speculation appears to be widespread that when a private group develops a sound concept for an atomic power system, the AEC may speed up or modify its program to convert the private plan into an AEC project, or discourage it by setting up a parallel project, or else prevent it by engaging the competent group involved on another AEC project. Another view is that no group is or has been about to start a large-scale atomic power project and that "it is all too easy to blame creeping bureaucracy" for a failure of private enterprise. There is also a view that the kind of long-range planning and investment involved in atomic power development may inevitably be interrupted by more intensified military efforts which both industry and Government are powerless to prevent because of international events. This view is attacked by others as "defeatism."

11. How Might Legislative Changes Affect Atomic Power Development?

Reactions to possibilities of legislative changes which might affect atomic power development were varied. Most of the individuals who had been associated with power-study projects were inclined to recommend putting off any and all revisions or additions to the Atomic Energy Act at least until one or more prototypes have been built and operated experimentally. These individuals were not at all certain that experience would prove that extensive legislative revisions are necessary at all, especially if Government ownership of all reactors proves to be workable.

There tended to be much more emphasis on the desirability of precise administrative regulations providing some degree of incentive for bolder private efforts. The advocates of this approach were invariably among those who have been attempting to develop concrete proposals during the past 18 months that would be acceptable in every way, to all parties concerned, within the structure of existing laws. If legislation substantially different from that now in force were to be proposed, these individuals expected that all planning would stop for at least 6 months while the Congress revised the laws; and then another year would be required to examine the implications of the

new legal provisions and prepare a variation on any previously examined proposal that could be put forward under the new provisions. Thus, legal revisions—which are in any case thought to be of questionable necessity, in the opinion of most who commented—are seen as possibly delaying private development for some months.

The proponents of legislative changes were largely industrial executives outside the utility industry. These individuals were disposed to discuss the possible need for over-all revision of large segments of the law, however, rather than particular provisions in direct relation to atomic power. One suggestion was made for a special Presidential commission to rethink the entire defense—atomic energy—policy-planning functions of the Federal Government.

Some specific changes or additions were nevertheless advocated by various individuals. For example, it was suggested that the patent provision should be revised so as to remove the prohibition on private patents. Another suggestion was that the security provision be revised so as to make the term "restricted data" more precise in definition or to permit categorizing "restricted data" in terms of degrees of sensitivity.

One executive summed up the most general feeling noted when he urged that no legislative changes be undertaken in the immediate future because, while the existing law is not ideal in the eyes of everyone who must live under its terms, it is vastly preferable to the "storm which would probably be stirred up" in the process of working out extensive changes.

12. What Is Retarding Atomic Power Development?

It was evident in every conversation that atomic power development has not been progressing as rapidly as those interested believe it could. The "delay" was attributed partly to technical difficulties, but these were held to explain the slowness of progress in the period immediately following World War II more than in the present. The relationship of government and private industry seemed to be the area in which most individuals felt the cause of the delay is to be found. Those interviewed perceived a tendency on the part of both those in private industry and in government to hold back in the hope that someone else will assume the responsibility in each problem area, that someone else will make the investment in the pilot or prototype plant, and that someone else will force the policy issues which must be decided before the atomic power industry can go forward aggressively.

Executives in private industry appear to believe there should be assurances that the government is willing to allow a private atomic power industry to develop, that risk-taking will be compensated by profits for success and financial allowances for failures, and that regulations will be established with progress and profit in mind as well as safety and security. Government executives want to see assurances that private industry is not seeking to create a subsidized industry which will always be directly dependent on public funds for its development and profitability. They are hesitant to jeopardize availability of the full strength of the atomic energy industry for accomplishment of military objectives.

One or two of those associated with neither government nor industry hope that resolution of the conflicts in public and private development will not be at the expense of balance between security and

progress. Private control must not supersede public ownership, in their view, solely because industry hopes that it may influence a government regulatory body more easily for its own ends than it could an operating government agency.

There were some legal problems noted among causes for delay. The utility companies fear that dual-purpose atomic power plants would place them under the restraints of the Public Utility Holding Company Act. If they seek to avoid this by spreading the support of a special atomic power development project among twenty-one or more companies, there is fear of action by the Anti-Trust Division of the Justice Department. Resolution of these conflicting fears is thought by some to depend on an official expression of intent by the Congress or the Executive Department. No one, however, stated that he has sought to obtain a resolving expression of intent.

Other tangible problems frequently noted were: guaranteed availability of fuel; access to "restricted data"; continuation of basic supporting research in the "national laboratories"; insurance of health and safety for workers and the surrounding communities; ownership of patents; freedom to locate plants on an economic basis; and freedom to market products on a profitable, competitive basis with realistic safety and security regulations.

Throughout the survey all prospects for atomic power development appeared to be dependent on a decision as to whether or not more plutonium will be needed to meet military requirements. If existing and planned capacity is adequate, then dual purpose reactors are not now believed to be commercially feasible either as power producers or as producers of plutonium for fuel. Power-only plants would then constitute the principal type on which industrial interest would center, but development of these plants is regarded as a bigger technological hurdle. If more plutonium is needed, however, several groups are currently interested in joint undertakings with the AEC in building dual purpose plants to sell plutonium to the government and to sell power commercially.

APPENDIX

APPENDIX A

The following are two concrete proposals for atomic power plant development. Other proposals less specifically formulated are to found in Appendix D.

1. A PROSPECTUS FOR DEVELOPMENT OF ATOMIC POWER THROUGH A SINGLE PURPOSE EXPERIMENTAL INDUSTRIAL REACTOR (SPEIR)

By George L. Weil,[1] September 13, 1952

INTRODUCTION

A Specific Program for a Single Purpose Nuclear Power Plant

This is to outline a program for the development of nuclear reactors for power for private and public use.

A specific technical program is suggested as a practical approach not now being explored or contemplated by the Government or industry.

The immediate objective is to determine the performance and economics of power production—through single-purpose reactors designed solely to measure and study realistically the economics of atomic power.

The program proposes a direct attack on the major development and engineering problems associated with minimizing the cost of power by establishing as its first task the design, construction, and operation of a single purpose experimental industrial reactor.[2]

A Nonprofit Organization

Public money has not taken this first practical step toward nuclear power.

Private enterprise has not, and probably will not, for some years to come.

But a combination of public, business, and philanthropic money could make an investment which would be a real achievement in public service—and point the way to further service and profit in the future.

It is proposed to establish a nonprofit organization which initially will be responsible for executing and administering the technical program by contract. Later the SPEIR project directly, through its own staff, would be responsible for operation of the plant, and its use in providing information on performance and economics of operation and in further development and engineering work.

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[1] George L. Weil has been active in the design and operation of research and production reactors, and in administration of the Atomic Energy Commission's reactor program. Since leaving the Commission in June 1952, he has been engaged in private consulting practice, with headquarters in Washington, D. C.

Dr. Weil entered the field of atomic energy in 1940 when he joined a group working under Prof. Enrico Fermi at Columbia University. When the metallurgical laboratory of the wartime Manhattan Engineer District was established at the University of Chicago, Dr. Weil transferred along with the rest of the Columbia group.

Dr. Weil was among those present on December 2, 1942, when the world's first sustained chain reaction was produced in the nuclear reaction built in the old squash court beneath Stagg Field at the University of Chicago.

At Chicago Dr. Weil worked on development, construction, and use of the pioneering reactors, and later he joined the du Pont Co. to assist in the early stages of the plutonium-production reactors at Hanford, Wash. In April of 1945 he went to Los Alamos, N. Mex., to work on the first test of the atomic bomb.

In October 1945, Maj. Gen. Leslie R. Groves appointed him to serve as United States scientific representative to the joint Canadian-UK atomic-energy project at Chalk River, Ontario, Canada. In January 1947, he left this work to become a research associate with the General Electric Co., at the AEC's Knolls Atomic Power Laboratory at Schenectady, N. Y. GE released him when he was appointed to the Division of Research of the AEC, and at the time of his resignation from the AEC he was Assistant Director of the Division of Reactor Development.

Dr. Weil was born in New York City and received his bachelor of arts degree from Harvard, and his master of arts and doctor of philosophy degrees from Columbia.

[2] Conveniently abbreviated to SPEIR.

SPEIR would focus and coordinate the interests and financial participation of governmental agencies and both profit and nonprofit private groups.

The Program Costs

The design of the single purpose experimental industrial reactor would be selected from a number of possible existing preliminary designs. The basic technology of each of these has been sufficiently developed under the Atomic Energy Commission's program to allow start of construction of a plant in about 1 year from time of authorization of the project. Construction would require about 2 years for completion. Following completion of construction, provision is made for 2 years of study. It is estimated that funds required for the project would be as follows:

Research and development (5 years)	$10,000,000
Engineering design	1,000,000
Construction	9,000,000
Total	20,000,000

The Need for a Single-Purpose Experimental Industrial Reactor

Since the demonstration 10 years ago that the controlled release of energy in nuclear reactors is possible, it has been known that at least in principle power plants operating on nuclear fuels could be built and operated. The technical feasibility of such systems has, however, not been demonstrated until quite recently. With regard to production costs for electrical energy from nuclear reactors, statements have been published both on the unrealistically optimistic and on the darkly pessimistic sides. With the clearer conception now available of engineering designs of power reactors, it is possible to make more realistic estimates of construction costs and performance. Some estimates indicate that full scale plants constructed on the basis of current technology might produce power, not subsidized by sale of any plutonium produced, in the range of about two to three times the cost of power from conventional plants in the United States.[3]

Although this is certainly not the "cheap power" predicted by many, it also is not in a discouragingly high range of cost. In fact, were the international political situation such as to make it expedient to consider the construction of nuclear power plants in power-hungry regions of the world not as favorably situated as we are, it appears that in such localities ***competitive power from nuclear plants would be practical today.***

The state of development on which the above estimate is based results from the technological advances which have accrued in the reactor development programs carried out during the last several years by the United States Atomic Energy Commission and by industrial contractors. The objectives of these programs have principally been military. It is reasonable to assume that with redirection of development efforts to provide a direct attack toward the single objective of economic power, significant decreases in power costs can be anticipated. Confidence in this assumption, together with the fact that the real costs of hydrocarbon power are on a slowly rising curve (for technological reasons independent of inflationary effects, is the basis for concluding that within a few decades nuclear power will compete on a wide scale with power from other fuels if the necessary development programs are undertaken.

Briefly, the immediate goal is the development of this new technology for the production of power to the point where its performance and utility can be economically compared with conventional methods for producing power. Such a development would provide, among other things, an added degree of flexibility, in public and private activities involving the defense of the Nation, the development of industry, and the use of natural resources in this country and elsewhere.

This development would enable this country to provide the underdeveloped and high-cost power regions of the world with an established technology upon which they could rapidly develop their own industrial economies, with concomitant gains in living standards throughout the world.

From the long-term point of view, the SPEIR program would represent a major step toward a system which is economically competitive on a large scale

[3] Persons who have appropriate AEC clearance will have access to classified data which further support discussions of certain subjects. These subjects include cost estimates, utilization of nuclear fuel, reactor designs, and technical problems. There is, of course, nothing in this prospectus of a "restricted" or secret nature.

with conventional methods of power production, and which would utilize the very sizable store of energy available in the uranium and thorium resources of the world. When the conditions of world peace are achieved, the United States will have on hand a substantial store of energy in the stockpile of atomic weapons. It is of importance that this Nation be prepared to utilize this stockpile of energy for the benefit of a peaceful world.

At present, neither the Atomic Energy Commission nor private industry is sponsoring a significant development effort in the production of economic power alone, that is, power not subsidized by military considerations. The United States Atomic Energy Commission has been forced by the international situation to concentrate its activities, for the present and the foreseeable future, on military applications for fissionable material. The magnitude of development effort required and the cost of construction of prototype nuclear power plants represent financial risks which industrial organizations are unwilling to assume at this point. Recent studies of possible participation by industrial groups with the Atomic Energy Commission have not produced any extensive programs along the desired lines.

In this dilemma, which has paralyzed the development of a technology of national importance and of widespread interest throughout the free world, private nonprofit institutions have an opportunity to occupy a unique position in providing not only financial assistance but the means for coordinating and focusing the interests of many diversified groups.

The proposed program involves the development, construction, and operation of an experimental nuclear reactor power plant designed with the *single objective* of producing the most economical electric power on the basis of current reactor technology and without subsidy through the sale of plutonium to the Government. Responsibility for the execution of this program would be assigned to a nonprofit organization. With adequate funds, estimated at $20 million, to cover development, construction, and operation for 2 years, the complete program could be accomplished in about 5 years. The achievement of the initial program objective would accomplish five purposes:

1. Establish the construction and power production costs for an operating single purpose experimental industrial reactor. The SPEIR plant would have a generating capacity of the order of 10,000 kilowatts. It could serve as a prototype for immediate installation in the United States or elsewhere in the world if need arose and circumstances permitted.

2. Provide a firm basis for estimating the cost of power from large industrial reactor plants. The impact of this new source of energy on the industrial development of the United States and other countries could then be evaluated in a realistic manner.

3. Provide experience in operating a power reactor complex.

4. Provide a facility for continued development work on improved designs of nuclear power plants.

5. Provide a facility for training of personnel from industrial concerns, engineering, and other interested organizations.

I. THE POTENTIALITIES OF A SINGLE PURPOSE NUCLEAR POWER PLANT

Comparison of Nuclear and Conventional Plants

In comparing a nuclear power plant for the production of electric energy with a conventional steam-electric plant, one finds that all of the equipment beyond the point at which steam is produced is common to both. The nuclear reactor and its heat exchanger for producing steam merely substitute for the conventional boiler and associated fuel handling equipment. To date, no practical method has been discovered for directly converting the fission energy into any other form than heat. This fact is important, for it immediately establishes a major element in the production cost of electric energy from nuclear plants.

On the basis of its technology as conceived today, the exploitation of nuclear energy depends upon the natural occurrence of the nuclear isotope known as Uranium–235, and the artificially produced isotopes Uranium–233 and Plutonium–239.

Fission as a Source of Energy

These isotopes, in their nuclear interaction with neutrons, undergo a process known as fission. Fission results in the release of an amount of energy relatively enormous in comparison with the energy release of ordinary chemical processes such as the burning of coal. Pound for pound, fissionable material releases almost 3 million times as much energy as does coal in burning.

Nuclear Reactor

The nuclear fuel (U–235) is fissioned (or burned) with the release of energy in a device known as a nuclear reactor. The reactor promotes and controls the fission process. The energy appears in the form of heat and is removed from the reactor by a suitable coolant.

Potential Advantages of Nuclear Power

It is evident that the successful development of a technology to put the fission process to practical application holds promise for adding to the world's rapidly depleting energy resources. Also, because of the unique characteristic provided by a basically costless fuel combined with mobility, it may provide electric power to many areas of the world where development is now limited by lack of economic access to water power and fossil fuel resources.

This promise for the future is based on three major premises. First, the natural resources of nuclear fuel are potentially capable of providing a significant contribution to the energy resources of the world. Second, it is technically feasible to produce useful energy from nuclear sources. Third, the inherent low cost of the energy contained in the nuclear fuel will be reflected in an over-all low production cost for electric energy.

Nuclear Fuel Resources

In discussing resources of nuclear fuel, it is desirable to distinguish between two types: (*a*) fissionable material, and (*b*) fertile material. Our prime fissionable material resource is uranium 235, which is contained in ordinary uranium to the extent of about 0.7 percent. Fertile materials known today consist of (*a*) uranium 238, which is predominant in ordinary uranium to the extent of about 99.3 percent; and (*b*) ordinary thorium, which consists of only one isotope, 232. These materials are called fertile since, by nuclear interactions, they can be converted into the fissionable materials plutonium (produced from uranium 238) and uranium 233 (produced from thorium 232) which can be used as nuclear fuels along with U–235.

Uranium-235 Resources

If we were dependent solely upon U–235 as the fuel for nuclear power plants, the amount available from relatively rich ores would be capable of supplying the world's total thermal requirements for the order of a few years to a quarter of a century.[4] "Long-run substitution of nuclear energy for power from conventional sources would then be possible only if practical (economic) methods are developed for the extraction of uranium from the widespread low-grade ores."[5]

Use of Fertile Materials

The process by which the more abundant fertile materials can be converted to nuclear fuel provides us with an economic alternative to the necessity of recovering uranium from very low grade ores. This process requires the seeding of the fertile materials with neutrons. It is a fortunate circumstance of nature that neutrons which can be used for this purpose are made available when U–235, or any nuclear fuel, is fissioned. Thus, in the act of consuming nuclear fuel for the production of energy, it is possible simultaneously to produce new nuclear fuel in roughly equivalent amounts.[6]

Significance of Fertile Materials

This process of continual equivalent replacement or regeneration of nuclear fuel can ultimately allow utilization of a significant fraction of the available uranium and thorium resources for production of nuclear power. However, so long as the production of new nuclear fuel is only equivalent to the amount consumed, the total available for power production at any one time would remain essentially constant and limited in amount to our economically available resources of U–235. Operation on this scale would be continued until practically all of

[4] A nuclear power plant of say 150,000 kilowatt capacity (electric power) would consume about 1 pound of U–235 per day. To supply the total annual electric energy production in the United States for the year 1950 (330,000,000,000 kilowatt-hours) would require the consumption of about 100 tons of U–235.

[5] W. Isard and V. Whitney, Atomic Power—An Economic and Social Analysis, the Blakiston Co., 1952, p. 19.

[6] This is not merely feasible "in principle," it is the basis of the Atomic Energy Commission's process for the production of plutonium for the weapons stockpile. As a matter of fact, the amount of plutonium produced is only slightly less than the amount of U–235 consumed.

the uranium (U–235 and U–238) and thorium resources have been consumed; a length of time which now becomes significant when compared to the lifetime, say, of our coal and oil resources. Even if one assumes that only 90 percent of the consumed fuel is regenerated, the situation, although less favorable, is still promising (refer to attachment A).

Breeding Process

But nature provides us with even brighter prospects—not with regard to the total available resources of nuclear energy, but rather in allowing us the opportunity for greater flexibility in utilizing these resources. It happens that not only are enough excess neutrons made available by fission to allow us to roughly replace our nuclear fuel as it is consumed, but there are neutrons even in excess of this requirement. This opens up the possibility of receiving a dividend of nuclear fuel as well as return of the investment. Thus, our nest egg of U–235 can, in principle, be expanded at a compounding rate if desired, to satisfy any annual requirements for nuclear power. This process, known as breeding, would not increase our total resources of nuclear fuel beyond those made available by equivalent regeneration but it would allow us to burn them up faster if this were desired.

Significance of Breeding

The significance of breeding, therefore, is not, as has been erroneously suggested many times, that it will make available from uranium 100 or more times as much nuclear fuel as a nonbreeding process, but rather that it is a method of increasing the fuel available at any one time without resorting to the possibly more expensive method of recovering uranium from very low grade ores. In the last analysis, breeding provides us with an alternative to expanding exploitation of natural resources. Either process can provide significant amounts of energy; at which point in the use of nuclear energy the one becomes more economical than the other will be determined by many factors.

In contrast to the technology which allows us to practically hold our own on fuel supply, the successful application of breeding is in a much less advanced state of development. Although nature tantalizes us with the prospects, she also has it so arranged as to make it technically difficult to achieve.

Summary of Nuclear Resources

To summarize, assuming unofficial minimum estimates of uranium and thorium ore reserves:[7]

(*a*) On the basis of efficient use of these reserves by regenerative processes now developed, nuclear fuel can provide a *significant contribution* to the world's *long-term* energy requirements.

(*b*) If the breeding process can be successfully developed, then nuclear fuel can achieve a place as a *major supplier* of the world's *annual* energy requirements.

Technical Feasibility of Nuclear Power

There is available today as a result of the wartime program and the programs sponsored by the Atomic Energy Commission, an extensive reactor technology. Significant technical contributions have resulted from the Atomic Energy Commission programs directed toward the development of mobile power plants for submarine propulsion. One program, being carried out jointly by the Westinghouse Electric Corp. and the Argonne National Laboratory, has concentrated on the development of a system using high-pressure water to extract the nuclear energy. Another major program, at the General Electric Co., has developed a system using a liquid metal for its heat transfer agent.

The Argonne National Laboratory has recently demonstrated, on a relatively small scale, the technical feasibility of producing power from a nuclear reactor.[8] An experimental reactor generated the order of 100 kilowatts of electrical power at the National Reactor Testing Station in Idaho. The heat energy generated was removed from the reactor by liquid metal at a temperature high enough to generate steam to drive the turbine.

How much would energy from a nuclear plant cost if one were constructed on the basis of present technology? Estimates made by groups of comparable competence vary from as low as 8 mills per kilowatt-hour to as high as 20 or 30 mills per kilowatt-hour. These estimates have been made on the basis of pre-

[7] John R. Menke, Nuclear Fission as a Source of Power, Cowles Commission Special Papers No. 1, 1947.

[8] Atomic Energy Commission, Press Release No. 407, December 29, 1951.

liminary engineering studies of several different basic plant designs. They are strongly influenced by the optimism or conservatism of the individuals involved.

Basic Conclusions on Power

On the basis of studies so far done, one can draw several conclusions. First, the technical and engineering information that is available is inadequate to provide accurate estimates of practical power costs. Second, a number of different basic designs appear to give comparable production costs—within the precision of the estimates. Third, it is generally agreed that the capital cost of a nuclear power plant will be at least two or three times as much as the same cost for a *comparable* conventional plant. Fourth, the greatest uncertainties in the estimates arise from lack of firm information on the extent that fuel can be utilized before reprocessing is necessary and the over-all performance of the plant that can be achieved in practice. Fifth, the over-all production cost of electric energy from a nuclear plant will almost surely be appreciably greater than present energy costs in the United States. Finally, the only way by which the estimates can be significantly refined and the range narrowed is by designing, constructing, and operating an experimental nuclear power plant.

One can discuss very qualitatively the outlook for nuclear power costs. What are the long-range possibilities?

Production costs can be broken down into three categories: First, fixed charges on investment in plant and equipment; second, cost of fuel and fuel handling; and third, other operating costs, for example, labor for maintenance and repair. Today, in conventional steam-electric plants in the United States, the percentage contributions of each of these items to the over-all production cost is roughly as follows:

	Percent
(A) Fixed charges:	
Boiler and fuel-handling equipment	25
Turbine-generator equipment	25
Total fixed charges on plant and equipment	50
(B) Fuel and fuel handling costs	35
(C) Other operating costs	15
Total	100

It has been pointed out that turbine-generator equipment and associated buildings, etc., will be common to both nuclear and conventional plants. We can reasonably assume that item (C), "other" operating costs, will be roughly the same for plants of the same capacity. We see immediately that the use of nuclear power cannot possibly affect roughly 40 percent of present power costs.

What shall we assume for the cost of the reactor and its heat exchanger? A reactor is a bulky and complicated machine. Many special materials go into its construction. There is no good reason to expect that this equipment would be cheap compared to boilers and other conventional equipment. Let us assume for the sake of arriving at a qualitative comparison of over-all production cost that the investments in plant and equipment would be comparable.

With regard to nuclear fuel costs, there is every reason to expect that ultimately the unique economic potentialities of the enormous concentration of energy can be realized in practice.

Assuming, then, a negligible cost for the nuclear fuel, we conclude that the long-range over-all production cost of electric energy from nuclear plants cannot be much less than about 65 percent of present costs from conventional plants. If we take 6 or 7 mills per kilowatt-hour as an average for conventional plants, then we might look forward to a nuclear energy cost of 4 to 5 mills per kilowatt-hour.

Although this is cheap, in comparison to average power costs throughout the world, it is not the costless energy that many predicted and hoped for.

What are the major technical or engineering problems that now contribute to making nuclear energy costs high?

Hazard in Reactor Operation

Current estimates of capital costs per kilowatt of generating capacity for nuclear plants indicate a factor of at least two or three over corresponding costs for conventional plants. There are two major elements that contribute to this cost. One is simply the fact that reactors are complicated machines.

The other is the fact that reactors contain large amounts of radioactive materials. In the event of malfunctioning of the plant, these materials constitute a potential hazard to surrounding communities. By proper choice of design of the plant the potential hazards can be considerably reduced. However, until there is confidence that the risks can be reduced to the level of normal industrial risks, it is likely that, in populated areas, land requirements and costs will be high.

There is every reason to expect that with imaginative engineering effort focussed on the objectives of minimizing construction and operating costs and maximizing performance and safety, the present estimated investment costs per kilowatt of capacity can, in the course of time, be significantly reduced. It may be noted that, according to the Edison Electric Institute, in 1882 the first electric power station required 30 to 40 pounds of coal to produce 1 kilowatt-hour of electric energy.[9] Today the average for the Nation is close to 1 pound of coal to produce the same energy.

The other major element in determining over-all production costs is fuel utilization. What are the technical problems now limiting fuel utilization? How close are we in practice to having a costless fuel?

Fuel Costs From Ore to Plant

The value of the thermal energy in nuclear fuel and the problems involved in keeping this cost low can best be discussed in following the fuel through the three major stages of its history.[10]

(1) In ore concentrates,
(2) In fabricated form prepared for loading into the power plant,
(3) In process of consumption in the power plant.

The Atomic Energy Commission has guaranteed to domestic ore producers prices ranging up to $3.50 a pound for uranium oxide contained in ore.[11] Since one pound of uranium oxide contains about 34 billion B. t. u., the cost of the basic heat energy amounts to about 0.01 cents per million B. t. u.[12] One can conclude, therefore, that even if the cost of uranium in ore concentrates should be 10 or even 100 times the quoted value for domestic production, the basic cost of the contained energy would still be negligible compared to the present average cost of energy in hydrocarbon fuels.

Value of Energy in Fuel Elements

Fabrication of the fuel elements includes all operations in processing uranium ore concentrates into fuel elements for the reactor. No prices are available to quote, but one can assume, on the basis of usual industrial chemical and metallurgical processing costs, that the additional work would not appreciably change the basic low cost advantage of nuclear fuel.

Problem of Fuel Utilization

Up to this point in calculating basic energy costs, it has been assumed that 100 percent of the fission energy contained in uranium can be converted into thermal energy once the fuel is inserted in the reactor, that is, that all of the fertile U–238 is converted into plutonium and consumed. We are faced at present with three very real technical difficulties which prevent such complete utilization of the fuel.

First, and least limiting, is the fact that as the fuel is consumed a point is eventually reached at which the amount of fissionable material remaining is less than the amount required for operation, and the reactor will no longer operate. Second, and more serious, as the fuel is consumed it produces "ashes," known as fission products, which inhibit normal operation of the reactor and eventually, unless removed by chemical processing, cause shut-down. Third, metallic uranium fuel elements suffer structural damage within a reactor as a result of the severe radiation effects which they must undergo.[13] This damage is made evident by pronounced physical distortion of the elements which, beyond a certain degree, cannot be tolerated within the reactor.

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[9] The Scientific Monthly, volume LXXV, No. 2, p. 103.
[10] It is assumed in this discussion that ordinary uranium is used as fuel.
[11] Atomic Energy Commission—Press Release No. 347, February 28, 1951.
[12] The cost of thermal energy from coal at central steam stations in the U. S. ranged in 1945 from about 12 to 41 cents per million B. t. u. Coal at $4 per ton is equivalent to about 15 cents per million B. t. u. (Reference: Isard & Whitney, Atomic Power—Table VI, p. 42.)
[13] Nuclear Fuel for Power Production, by John F. Flagg and M. J. Gross, AECU–1631.

Limitations on Fuel Utilization

These effects, particularly the latter two, now require that metallic uranium fuel elements be discharged from the reactor after only a very small fraction of the uranium has been consumed. At this point the fuel can either be stored for possible future economic recovery or it can be chemically processed to remove the harmful fission products and refabricated into sound fuel elements. Which of these courses is the most economical one to follow depends upon many factors—but primarily upon the extent of utilization of the fuel that can in practice be achieved. It is worth noting that if as much as 1 percent of the fuel is utilized, the resulting basic net energy cost in the ore concentrates would be about 1.0 cents per million B. t. u., which is still small compared to the average cost of energy in coal.

Chemical Reprocessing

As an economic alternative to storing partially used fuel, chemical reprocessing and refabrication introduce both additional operating costs and fixed charges. The chemical operations are very costly because of requirements for special equipment and plant design for safety handling the highly radioactive materials. If this course is to be economically justified then the value of the fuel at the time reprocessing becomes necessary must at least compensate for the increase in operating and fixed charges.

These problems do not interpose insurmountable obstacles to the development of cheap nuclear power. Quite the contrary, there are indications today that solutions can be found. But the degree of fuel utilization that can be achieved in practice is an important factor in determining the cost of nuclear power today.

Other Operating Costs

With regard to "other operating costs," there is no reason to expect that, after experience is gained with nuclear plants, there would be significant differences compared to corresponding costs for conventional plants.

Summary of Component Costs

To summarize, a qualitative comparison of the major components of the cost of generating electric power by a nuclear plant and a conventional plant has indicated that:

(*a*) The investment cost per kilowatt of electric generating capacity for a nuclear plant may at present be two or three times as great as the corresponding investment cost for a conventional plant. With determined and imaginative engineering effort focused on the problems, there is good reason to believe that this differential can be considerably reduced.

(*b*) The fuel costs for the nuclear plant will not be negligible at first, but there is real hope that improved technologies now in the research stage will eventually provide significant savings in this area. These savings can be used to offset greater fixed charges of the reactor as compared to the conventional boiler.

(*c*) Operating costs should be comparable.

Significance of "Economic Nuclear Power"

What production costs for nuclear power would be considered "economic," or competitive, in the world today, or say within the next decade? Since the cost of power from conventional plants varies widely throughout the world, and even in the United States, the term "economic" nuclear power has meaning only in defining a cost in a particular locality. A production cost that would be far from economic in the United States might well be economic at some undeveloped source of vital raw material in another part of the world.

Competitive Position of Nuclear Power in the United States

In the United States production costs of electric energy from large conventional thermal-electric plants average about 6 to 7 mills per kilowatt hour.[14] It is also pertinent that the total generating capacity in the United States during the last 25 or 30 years has been expanding at a rate corresponding to a doubling of capacity every 10 years.[15] On the basis of best estimates of the United States hydro and hydrocarbon energy resources, it is concluded that, on the average, the real costs of producing electric energy in the United States

[14] At the bus bar and for 50 percent plant capacity.
[15] President's Materials Policy Commission Report, vol. I, p. 103. United States Government Printing Office, Washington, 1952.

will not materially increase in the period to 1975.[16] The cost trend in specific areas may indeed rise, particularly in areas which now have limited local resources of cheap energy, for example gas fields or hydro. With regard to large scale use of nuclear energy in the United States, therefore, it is unlikely that nuclear power will play an important role in our national economy for 25 years or more. However, in the longer term, we can anticipate a gradual convergence of real production costs.[17]

Growth of Nuclear Power in the United States

A natural growth of nuclear power in the United States will initially involve limited application in localities where costs are high primarily as a result of a fuel transportation over large distances. Such situations are most likely to exist at isolated natural sources of strategic materials.[18] The possible importance of nuclear power in developing such sources efficiently is stressed in the recent report of the President's Materials Policy Commission.[19] It is reasonable to anticipate that with improvements in technology and reduction in production costs, nuclear power will gradually be capable of competing with conventional sources in an ever increasing number of situations in the United States

Military Uses of Nuclear Power

With regard to military uses, the situation today may be much more favorable economically. The power requirements at isolated military bases, which are rapidly multiplying, might well be most effectively satisfied by means of small nuclear plants.

Competitive Position of Nuclear Power in Other Free-World Nations

The other free nations of the world are not all as richly endowed with easily accessible and high-grade natural resources of fuel as in the United States. With regard to their energy demands, the President's Materials Policy Commission reports:

> "The level of total free world energy demand by 1975 will be determined by a variety of unforeseeable forces and events. A plausible projection, assuming reasonably favorable conditions, would be something close to a doubling of demand * * * The greatest percentage increase is looked for in the less-developed areas where industrialization is just getting underway, whereas demand in Western Europe will probably increase somewhat less than in other areas.
>
> "Western Europe nevertheless faces a particularly serious energy problem. Continued economic progress will depend in large part upon industrial processing and transportation—both heavy users of electricity and fuel, but the European economy is poorly equipped with resources to meet these demands. Dependent in the past upon coal as its dominant source of energy, Western Europe now faces increasing difficulty in obtaining coal from poorer seams at greater depths. So far as is known, the area has only meager gas and oil resources, though recent discoveries may lead to finding additional reserves.
>
> "Expansion of industrial activity more rapidly than coal production in recent years has led to large imports of coal from the United States at prices up to $25 a ton (transportation was most of the cost), causing a heavy dollar drain on Europe and indirectly upon United States foreign aid * * * *Electric power or heat from atomic energy may become economically feasible in Europe before it does in the United States, because of the basically higher energy costs in that area.*" [20]

Development of Nuclear Power by Western European Nations

Recognition of the important role that nuclear power might play in the future economies of Western Europe is evidenced by the efforts which are now being devoted by some of these nations to atomic energy programs. Great Britain and France each has two operating research reactors. Norway and Holland have cooperated in the design, construction and use of a research reactor located in Norway. Canada, which has its own interests in the development of nuclear power, is collaborating closely with Great Britain in her program. Canada now has one major research reactor in operation and is in the process of constructing

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[16] President's Materials Policy Commission Report, vol. I, p. 104.
[17] President's Materials Policy Commission Report, vol. I, p. 129.
[18] Eureka mining area, Nevada. Article in Las Vegas Review Journal, July 23, 1952.
[19] President's Materials Policy Commission Report, vol. IV, p. 21.
[20] President's Material Policy Commission Report, vol. I, pp. 122–123. (Note: Italics supplied by George L. Weil.

a second. It is reported that Belgium is planning to construct a nuclear reactor. With the exception of Great Britain, who is also engaged in production of atomic weapons, other countries are primarily concerned with atomic energy as a source of power.

These programs are significant not only because they indicate the importance which these nations now attribute to nuclear power [21] but also because of their effect in eventually making obsolete United States policy of maintaining secrecy in this field.

Competitive Position of Nuclear Power in Latin America

Of the free world nations, those in which nuclear power might have the most immediate applications are the republics of Latin America. Except in isolated instances such as Venezuela, fuel resources are of low grade, of limited extent, or almost completely lacking. In many inland areas of Central and South America energy costs, produced by plants of small capacity, are in the range of 10 to 15 cents a kilowatt hour, and sometimes higher. Economies could in many instances be realized if the total power production capability of the many small hydro plants in one area were to be consolidated in a single large steam-electric plant. In evaluating the possible economic advantages of nuclear power over conventional power in such situations, it is, of course, important to distinguish between high costs which would be common to both types of plants, such as construction, and those attributable to fuel transportation. In those instances in which the latter factor accounts predominately for the high energy cost, nuclear power in its present state of development might well prove to be economical.

Summary of Section I

Within restrictions imposed by secrecy, section II has attempted to demonstrate that:

(*a*) There are sufficient raw materials to assure that, with appropriate technical developments, nuclear energy can ultimately play a major role in satisfying the world's energy requirements.

(*b*) The production of electric energy by nuclear reactors is technically feasible today.

(*c*) The next major advance in developing economic nuclear power must involve the focusing of technical and engineering effort on the problems associated with producing electric energy at low cost.

(*d*) It is highly probable that if power-producing nuclear reactors were constructed on the basis of current technology they could compete economically with conventional methods of producing power at a limited number of locations in the United States (and military bases) and, more widely, in many areas of the free world.

II. PROPOSED PROGRAM, FINANCING, ORGANIZATION, AND OPERATIONS

Desired Technical and Economic Data

In contrast to the general acceptance of the technical feasibility of nuclear power, there exists today a wide area of uncertainty as to the performance and over-all economics of operation which can be achieved with a nuclear-power plant. This uncertainty has been a major factor in discouraging financial interest by private enterprise and in blocking the consideration of nuclear power as a possible conventional industrial process at locations where fuel costs are high. This type of information can be obtained most effectively and conclusively if (*a*) technical and engineering effort is focused on the development of the most economic design of a single-purpose nuclear-power plant; (*b*) such a plant is constructed to demonstrate the practical feasibility of the design, and actual construction costs; and (*c*) the plant is operated to establish performance and provide practical information for determining realistic costs for production of electric energy.

Immediate Objective of Proposed Program

The proposed program, therefore, envisages as its immediate objective the development, engineering design, and construction of a single-purpose experimental industrial reactor. The SPEIR plant would be designed solely to provide

[21] This importance should be measured in terms of the effort devoted compared to the total resources of the nations.

electric power at lowest possible cost, without subsidy through the sale of plutonium for military uses. The basic design of the reactor would be selected from a number of existing conceptions which are today considered to be technically feasible. These designs would use ordinary uranium or uranium very slightly enriched in the U–235 isotope as fuel. Ordinary or heavy water at high pressure or a liquid metal would be used as coolant to extract the heat energy.

Since the objectives of the program are primarily to obtain valid information on costs and performance, it is desirable to establish as the basic criterion for selection of power output that capacity which will require the least expenditure of funds for plant equipment without sacrificing or compromising the desired engineering and economic information. On this basis, it is anticipated that the plant might have a thermal output in the neighborhood of 50,000 kilowatts, and an electric-generating capacity of perhaps 10,000 kilowatts.

Broad Phases of Program

The technical program can be broken down into three broad phases:

Phase I—Preliminary studies, research and development:

(*a*) Over-all engineering studies and comparison of several possible basic designs.

(*b*) Research and development in support of studies.

(*c*) Selection of the most appropriate basic design for construction.

(*d*) Determination of specific research and development program.

(*e*) Cost estimates for further research and development, engineering and construction.

Phase II—Development, detailed engineering and construction:

(*a*) Performance of necessary research and development in support of design selected.

(*b*) Component mock-up and testing.

(*c*) Detailed engineering of plant and associated facilities.

(*d*) Construction of plant and associated facilities.

Phase III—Research and development with experimental nuclear power plant:

(*a*) Studies and evaluation of technical, engineering, and economic aspects of the plant performance.

(*b*) Development of improved fuel elements and other reactor components.

(*c*) Studies of operating problems imposed by industrial uses.

(*d*) Development of design and engineering of improved nuclear power plant.

(*e*) Other appropriate research and development in the field of atomic energy.

Estimates of Program Costs

Until a specific program is established, a site and a reactor design selected, it is not possible to provide more than rough estimates regarding both time schedule and costs. Such estimates [22] follow:

	Time	Cost	
		Operations	Engineering design and construction
Phase I	First year	$1,500,000	
Phase II	Second and third years	4,500,000	$10,000,000
Phase III	Fourth and fifth years	4,000,000	
Total		10,000,000	10,000,000

Proposed Sources of Funds

It is proposed to finance the program by soliciting support from three groups, (1) Government agencies, [23] (2) private foundations and other nonprofit institutions, and (3) industrial concerns.

[22] These estimates are based on a specific program prepared by the atomic-energy research department, North American Aviation Co., Downey, Calif.

[23] Support from interested individual branches of the Government might all be coordinated through the Atomic Energy Commission.

Considerations in Allocating Requests for Support

In making preliminary allocations of the funds required among the three groups, three major considerations provide a basis for arriving at rough estimates. First, a Government agency such as the Atomic Energy Commission has considerably more flexibility in its use of funds appropriated for "Operations" compared to its use of funds appropriated for "Plant and equipment." This suggests that the Government agencies be requested to provide funds for operating expenses rather than for plant construction. Second, since the matter of ownership of the facilities (the experimental nuclear-power plant in particular) will raise some interesting contractual and legal problems, it would be administratively prudent to allocate the provision of funds for plant and equipment to a single or small group of organizations. Third, the selection of private nonprofit organizations as this group might eliminate some of the immediate administrative and contractual difficulties which now prove to be obstacles to any extensive participation by profit organizations. Fourth, on the basis of preliminary discussions with representatives of a small number of industrial concerns, and also in the light of the substance of proposals that have been recently submitted to the Atomic Energy Commission,[24] [25] a tentative estimate of annual support which might be expected from these sources would fall in the range of a few hundred thousand dollars to a million dollars.

Tentative Allocation of Supporting Funds

Within this framework, therefore, a tentative allocation of requests for funds could be somewhat as follows:

	Average per annum	5-year total
Operations:		
Industry	$600,000	$3,000,000
Government	1,400,000	7,000,000
Plant and equipment: Private nonprofit institutions		10,000,000
Total		20,000,000

Nature of Proposed Organization

It is proposed to establish a nonprofit organization to coordinate the financial and program interests of the several participating groups and to be responsible for accomplishing the program. At this stage it is neither possible nor desirable to present a detailed description of this organization. The principal officers, charter of incorporation, administrative policies, and methods of operation can only be developed in accordance with the desires of and in cooperation with the participating groups. However, in any arrangement it would be desirable to constitute a board of trustees, or directors, representing in proper proportion, the interest of the participating groups and under whose continuing guidance the broad programs and policies of the new organization would be established.

Management Functions

There are three possible approaches to the problem of providing for management functions. First, the new organization could recruit experienced management personnel. Second, the organization could contract with established industrial or other concerns for competent management services. Third, the organization could be created as a subsidiary group of an established nonprofit institution with adequate capacity to absorb the additional management and administrative functions.

Initial Operations

With regard to a method for accomplishing the program, the following procedure is tentatively proposed at this time. It is proposed to initiate work under phases I and II of the program by contract with existing groups adequately equipped with both staff and facilities.[26] Such groups that might be available

[24] Atomic Energy Commission press release No. 422, April 22, 1952.
[25] Remarks of E. J. Putzell, Jr., Monsanto Chemical Co., at University of Michigan Law School summer institute, Ann Arbor, June 26, 1952.
[26] The detailed engineering and construction of the experimental nuclear-power plant would be done by contract in any case.

for consideration include (1) atomic-energy research department, North American Aviation Co., Downey, Calif.; (2) Walter A. Kidde Nuclear Laboratories, New York, N. Y.; (3) Nuclear Development Associates, White Plains, N. Y.; (4) atomic-energy division, research laboratory, Bendix Aviation Corp., Detroit, Mich. In addition, it is possible that one or more of the industrial concerns that have been engaged in studies of dual-purpose reactors might be available. These concerns have now developed technical and design groups which are familiar with and competent to deal with problems of reactor engineering and design.

Initial Activities and Staff Requirements

The functions and activities of the new organization during the period of operation by contract would be primarily to (1) establish a specific program; (2) negotiate and administer contracts; (3) provide broad technical guidance to the programs under contract; (4) coordinate the several programs; (5) continuously evaluate the technical developments and plan the future course of the project. It is estimated that, as a minimum, the new organization would require a technical and engineering staff of four or five senior men, supported by an administrative and clerical staff. A part, or even all, of the technical staff might conceivably be obtained on an on-loan basis from industrial concerns.

Growth of Organization, Ultimate Activities and Staff Requirements

During the course of this period, facilities and equipment would be made available for the new organization at the site of the experimental plant. As these were completed, the organization would assume an increasing amount of direct responsibility for executing the program, and ultimately would be prepared to operate the plant and perform the desired research and development program in its own facilities and with its own staff. It is estimated[27] that the organization will eventually require a total technical staff, engineers and scientists, numbering about 50, together with additional staff of supporting technicians, computers, draftsmen, mechanics, etc.

Reasons for Proposed Method of Operation

The above approach to performing the initial phases of the program accomplishes four purposes:

(1) Avoids delays in initiating the project which would be occasioned by the necessity of building up a sizable technical organization and providing facilities and equipment for experimental work.

(2) Takes maximum advantage of existing technical organizations that have individually developed well-trained and coordinated staffs that have, in turn, studied and worked closely with the problems of nuclear power and have developed preliminary plant designs.

(3) Provides financial savings to the proposed project in making it unnecessary to construct and furnish facilities for experimental work other than those which will eventually be required at the site of the experimental nuclear-power plant.

(4) Provides opportunity for the new organization to build up its own technical and administrative staff in a sound manner in preparation for assuming direct responsibility for executing the program as soon as facilities are completed at the plant site.

Staffing by "On Loan" Arrangements

When the plant is in operation, it can be anticipated that the working staff will be augmented through scientists and engineers on loan from industrial concerns, educational institutions, Atomic Energy Commission laboratories, and other organizations, for purposes of performing experimental studies and/or training in the field of nuclear-power-plant design and operation.

Future of Organization

What about the future of the new organization? If the results of the experiment to produce "economic" nuclear power are favorable, then the possibility will exist of arousing active interest and financial support from private enterprise. However, the realization at that time of this support will depend largely upon the success which has been achieved in the interim in eliminating legislative restrictions which, in their present form, would handicap or even block widespread private uses of nuclear power. If an atmosphere, technical and political,

[27] Based on a program outlined by the atomic-energy research department, North American Aviation Co., Downey, Calif.

conducive to the continued and accelerated advancement of nuclear power can be achieved, then the organization could continue as an integral part of this program, supported primarily by industrial contracts. If, on the other hand, the proper atmosphere does not develop, then it is likely that the organization, its plant and its facilities, could continue to function effectively in research and development activities directed toward the goal of cheap nuclear power and under the auspices of public as well as industrial organizations. Whether the new organization could most effectively continue its operations as a nonprofit corporation or whether it would be advisable to reconstitute itself in the form of a profit corporation is a question that could best be answered at a later time.

III. DISCUSSION OF PROPOSED PROGRAM

Location of Experimental Plant

Choice of location for the experimental nuclear-power plant would be determined on the basis of a number of factors, principally economy and convenience. The National Reactor Testing Station at Arco, Idaho, operated by the Atomic Energy Commission, would provide financial savings. Land and numerous service facilities would be available at no cost. A disadvantage would be the isolation, which for a reactor of the type proposed would not only be unnecessary but even undesirable from the point of view of promoting the public and industrial acceptance of nuclear-power plants. Careful consideration would be given to locating the plant at a site where a nominal amount of power is required. Revenue from the sale of this power at local market value would contribute to the cost of operation of the experimental plant. The selection of a site would have to be settled prior to initiation of the detailed design work.

Capacity of Experimental Plant

The selection of a pilot-scale plant is proposed for two reasons: First, for economy in plant investment; and, second, a plant of this capacity could well be a prototype for many applications. The cost of the power from such a plant would be considerably greater than for a correspondingly designed large-scale plant. The fact that many economies can be realized in scaling up a plant is well proven in practice. In the case of conventional thermal-electric plants the cost per kilowatt of electric-generating capacity may be more than twice as great for plants of low capacity as for plants of high capacity.

Utilization of Plutonium To Replenish Fuel

The fact that the proposed experimental power plant would operate with ordinary or slightly enriched uranium implies that plutonium would be produced within the fuel in the course of operation. The production of this plutonium and its ability to replace as fuel the U–235 which is consumed in the fuel elements are the bases for the hope that fuel costs can be kept low.[28] In the program as proposed, no provision will be made in the form of special facilities for extraction of plutonium for weapons use—on the contrary, every effort will be made to prolong the life of the fuel element in the reactor and to consume the produced plutonium as fuel.

Reprocessing of Fuel

It would, in fact, be desirable to avoid completely the necessity for chemical and metallurgical reprocessing of the fuel elements during the proposed 2-year period of plant operation. However, if such reprocessing does become essential as the result of physical changes in the elements, it is likely that arrangements could be made with the Atomic Energy Commission for use of its facilities.[29] Additional costs to cover reprocessing would be included as operating charges. Whether or not this will be necessary can be answered with more confidence when a reactor design has been selected.

Availability of Nuclear Fuel

A question naturally arises with regard to the availability of nuclear fuel from the Atomic Energy Commission for such a program—particularly since no

[28] There is a well-defined conflict in design and operating procedures of a reactor depending upon whether plutonium or power is the product of major interest. Refer to discussion of dual-purpose reactors.

[29] The amount of material involved in the type of experimental reactor proposed would be relatively small.

contribution to the weapons stockpile is contemplated.[30] Definite commitments from the Atomic Energy Commission can, of course, only be obtained when a specific program is established and a proposal submitted. However, certain factors can be pointed out at this time which make the prospects appear to be favorable. First, the program does have aspects which are of decided interest to the military. Second, the amount of fissionable material required would be relatively small. Finally, the executive and legislative branches of the Government have publicly expressed strong interest and determination to promote the development of nuclear power for public and industrial use.[31]

Liaison With Atomic Energy Commission Programs

The technical program would be closely tied in all phases with classified work in laboratories operated under contract for the Atomic Energy Commission. It would be essential for the success of the program, therefore, that a close working relationship be arranged and maintained with these laboratories. It is not anticipated that any difficulty would be encountered in arriving at such a satisfactory arrangement.

Classification of Project

The SPEIR program would deal with "restricted data" as defined in the Atomic Energy Act of 1946. The program, therefore, would be classified as "secret" and would be required to comply with established security regulations for such projects.

Legislative Restrictions

In addition to placing restrictions on the control and dissemination of classified information, the Atomic Energy Act limits other matters which are of major concern to any private organization which engages in atomic-energy activities. These matters include the ownership and/or control of (1) fissionable and source materials, (2) certain types of facilities, and (3) patent rights. (A copy of the act is contained in attachment C.)

Interpretation and Significance of Legal Aspects

Meaningful interpretations of these and other passages of the Atomic Energy Act can only be made specific in relation to a well defined project. Similarly, their significance can only be appreciated in relation to the individual interests of the participating groups. It is proposed, therefore, that a detailed study and evaluation of the project's legal aspects be conducted concurrently with efforts to establish a working organization.

Premises on Which Program Is Based

In addition to statements concerning the technical feasibility and estimated range of power costs for single-purpose nuclear-power plants that may be constructed in the immediate future (matters that have been discussed in sec. II) the SPEIR program is proposed on the basis of the validity of the following three statements:

(1) Definite interests *now exist* among public and private groups in the United States for the technical and economic information which the proposed program is specifically designed to provide, namely:

(*a*) A proven design of a nuclear power plant which could be duplicated if needed; and

(*b*) Reliable information on the performance of nuclear power plants which can be achieved on the basis of present technology.

(2) Current and planned programs in the field of nuclear energy will not provide the information and technology now desired.

(3) It is necessary and desirable to obtain support from public and private organizations (including nonprofit as well as profit organizations) in order to establish a program of the nature proposed.

The first statement can be most conveniently discussed if the groups having interests in the program are considered in two broad categories:

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[30] If a national emergency did arise, and it was determined that the fissionable material could be effectively used in the weapons-production program, the power plant could be shut down, the fuel discharged, and returned to the bomb-production line.

[31] Representative Henry M. Jackson, member of the Joint Committee on Atomic Energy, has recently stated that it is now time that the development of nuclear power be taken "out of the laboratory and into the production shop." (Reported in Nucleonics, vol. 10, No. 8, August 1952, p. 72.)

(*a*) Governmental (including military) and private nonprofit organizations.

(*b*) Industrial (profit) organizations.

Interest of Public and Private Nonprofit Groups in Program—Nuclear Power in Point 4 Programs

Governmental agencies[32] and private nonprofit institutions are considered together, since their interests and activities overlap in many areas. In both these groups particular organizations are concerned with the broad objectives of the Point 4 Program. These objectives are being attacked at present primarily through programs designed to raise the standard of living in underdeveloped nations. It is well recognized that success along this line in one area of the free world promotes the economic well-being of all nations. It is also well established that the standard of living of any area is closely related to its industrial development, the growth of which, in turn, depends largely on the availability and cost of power at that location.[33] Since power costs in many underdeveloped areas are unusually high due to isolation from sources of fuel or water power, the technology of economic nuclear power, if it were available, might well play a significant role in foreign-aid programs. Schurr and Marschak have stated that—

> * * * the substitution of atomic power for coal in backward countries has potential importance in a number of ways: (1) it may lead to a cheapening of power; (2) it may be substituted for coal in certain uses, in countries having a relatively limited supply of that mineral; and (3) under certain circumstances it may permit a reduction in the capital required for industrialization by reducing the investment required in dams, transmission lines, mines, and railroads.[34]

Nuclear Power in Development of Natural Resources

Closely related to improving standards of living in promoting the strength of the free world is the development of new sources of strategic raw materials. The recent report of the President's Materials Policy Commission has focused attention on the seriousness of impending shortages for the United States and the rest of the free world. The development of practical nuclear-power plants by the United States may aid the situation in three ways. First, it may provide cheaper power than conventional plants at isolated locations of natural resources. Second, it would provide a greater flexibility in our ability to make most effective use of materials which are available, particularly hydrocarbon fuels. Third, it would provide us with a technology which could be made available to other nations having an economic need for nuclear power in exchange for raw materials to relieve United States shortages.[35]

The importance that is attached to the role which nuclear power might play in meeting the materials-shortage problem is emphasized by the following passage from the Report of the President's Materials Policy Commission:

> "An important economic advantage of atomic power is that not only is nuclear-fuel cost relative to energy produced almost negligible but the bulk of fuel required is small—an important consideration for areas remote from conventional fuel sources. These two factors open up the possibility of providing energy for developing and processing resources in areas now considered too inaccessible to be economic. Mining and beneficiating, and possibly even smelting, operations for valuable materials in such areas would thus become practicable."[36]

Nuclear Power in Defense Efforts

The United States military interests at this time in the development of nuclear-power plants include uses which have been discussed in the preceding paragraphs. The importance to the military of development of natural resources and provision of an adequate supply of raw materials is obvious. With regard

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[32] Department of Defense, Department of State (Technical Cooperation Administration), Mutual Security Agency.

[33] Isard & Whitney, Atomic Power, pp. 165, 168, 171.

[34] Sam H. Schurr & Jacob Marschak, Economic Aspects of Atomic Power (Princeton: Princeton University Press, 1950, for the Cowles Commission for Research in Economics), p. 264.

[35] Report of the President's Materials Policy Commission, vol. I, p. 3: "The destinies of the United States and the rest of the free world are inextricably bound together. * * * If the United States is to increase its imports of materials it must return in other forms strength for strength to match what it receives."

[36] Report of the President's Materials Policy Commission, vol. IV, p. 21.

to the more intangible benefits derived from improved standards of living, the President's International Development Advisory Board has this to say:

> "The Advisory Board feels that strengthening the economics of the underdeveloped regions and an improvement in their living levels must be considered a vital part of our own defense mobilization."[37]

More recently, Mr. Stanley Andrews, Technical Cooperation Administrator in the State Department, wrote:

> "There are many weapons which the free world can use to fight Communist aggression—military, political, and economic weapons. But I believe history may well demonstrate that the most effective weapon we have in the struggle against communism is the Point 4 Program. * * *
>
> "Point 4 is not a product of our defense effort and it is not a substitute for defense, but Point 4 is no less a source of strength for the free world."[38]

Nuclear Power for Military Bases

More directly, the military have an immediate interest in the possible economic use of nuclear-power plants to supply energy at isolated bases far from sources of conventional fuels. The required plant capacities in these instances, as in those to satisfy the needs of underdeveloped areas and at isolated sources of strategic raw materials, would very probably fall in the range of the experimental plant proposed for construction. Thus, this plant could be considered as an operating prototype which could be duplicated in short time with complete confidence in its performance. Even if no requirement existed immediately for such plants, the military potential would be strengthened in having available a proven design for construction if and when a need developed.

Broad United States Policy

Finally, we must recognize the fact that other nations, having at present a much greater internal industrial economic incentive than the United States, are proceeding with the development of nuclear-power plants for their own use. A sound United States policy would be to maintain the technological leadership which we now possess and to cooperate with these other countries of the free world to our mutual benefit.

Legislative Obstacles to Utilization of Nuclear Power

It should be made clear at this point that the Atomic Energy Act, *in its present form*, presents obstacles to any program which contemplates providing United States fissionable material and technological aid for the construction of reactors in foreign countries. Equally important, therefore, to the accomplishment of the program proposed is a thorough review of the act and necessary revisions to allow full utilization of the potential benefits described above. Efforts along these lines should be pursued vigorously and concurrently with the engineering and construction program. It will make little sense to perpetuate strict limitations and interpretations of the Atomic Energy Act with regard to divulging the technology of nuclear power in the face of foreign developments along similar lines and over which we have no control. Since most of these countries are not concerned with an atomic-weapons-production program but solely with commercial uses of nuclear power, there will be every reason for them to proceed on an unclassified basis, restricted only by the usual industrial practices.

Interests of Industrial Groups in Program

Industrial interests in the proposed program are distinguished from the interests of public and nonprofit organizations primarily in being motivated and guided by established principles of sound investment.

In discussing industrial organizations, one can distinguish between two broad groups. One group includes those organizations which may see a potential gain for themselves if nuclear-power plants were available in the immediate future and their use not unduly restricted. The other group includes those organizations which are primarily concerned at this time because of possible economic significance of nuclear power in their long-range planning. Any such broad grouping naturally invites a considerable area of overlap when considering the interests of any one concern. However, for the sake of brevity and at the expense of completeness, industries will be considered by type in one group or the other.

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[37] Partners in Progress, a report to the President by the International Development Advisory Board, March 1951, p. 1.

[38] The Washington Post, September 3, 1952.

Industries Having Most Immediate Interest

Industries in the United States which might stand to gain most immediately if a prototype single-purpose nuclear-power plant were available are those engaged in—

(*a*) Mining.
(*b*) Large-equipment manufacturing.
(*c*) Engineering-construction.

Mining Industry

The mining industry's interest stems exclusively from the fact that the locations of ore reserves are often extremely isolated from established power systems or fuel supplies. Such situations exist today in the United States where production costs for power run as high as 30 to 40 mills per kilowatt-hour.[39] A detailed report of such a site located in Nevada is presented in attachment B.

Equipment Manufacturing and Engineering-Construction Industries

The equipment-manufacturing and the engineering-construction industries could anticipate in the relatively near future the real possibility of supplying their services for the design, construction, and installation of nuclear-power plants. The foreseeable market for such plants, designed on the basis of the proposed pilot nuclear-power plant as a prototype, includes applications at domestic mine sites, military bases, and more widely, if legislative restrictions are removed, at locations of present high-power costs in many areas of the free world. These industries should be aware of the fact that other nations are intent upon developing and using nuclear power for commercial purposes. Consequently, not only will a foreign market develop independently of any activities in the United States to promote such development but many foreign concerns will take advantage of opportunities to provide power plants in less technologically advanced areas of the world.

Industries Having Long-Range Interests

The second group includes industries in the United States which on the whole do not visualize any particular immediate gains to their operations if proven nuclear-power plants were available in the near future. However, because of the significance of power in their operations, these industries do have an immediate interest in the type of information which will allow them to evaluate realistically the present status of nuclear-power development and its possible role in the planning of future operations and expansions. The major industries included in this second group are—

(*a*) Power utilities.
(*b*) Heavy power-consuming industries.
(*c*) Transportation.

Power Utilities

Although in the long run the power utilities will probably have the greatest financial interest in utilization of nuclear power, at the moment, and for the immediate future, this interest can be expected to be on a relatively small scale.[40] The attitude within the industry varies considerably among the numerous utility systems depending primarily upon the extent of cheap fuel resources available to individual systems. This is not to say that the power industry is not interested in nuclear power development at this time. Quite the contrary, any industry that is spending at the rate of almost $2 billion a year in expanding production capacity[41] must be well posted on the status of new technologies which are destined to play significant roles in its future operations. The Sporn committee advised the Atomic Energy Commission:

> "The nature of the industry's interest in nuclear reactors can * * * be stated in terms which describe its role in the changing technology of conventional power production: In order to make wise current plans and prudent investments for the future the industry must at all times keep abreast of developments relating to power production and what they foreshadow; in order to keep costs down and improve service, the industry must

[39] Senator George W. Malone (Nevada), Is Useful Nuclear Power Only a Year Away? American Engineer, May 1952.
[40] E. W. Morehouse, Walter Seymour, and Philip Sporn, Report to U. S. Atomic Energy Commission by Ad Hoc Advisory Committee on Cooperation Between Electric Power Industry and AEC. March 1951.
[41] The Wall Street Journal, August 11, 1952.

contribute as directly and as effectively as it can to promoting advances in technology." [42]

The proposed program would provide the type of information which can be of real use in evaluating the status of nuclear power relative to present and planned plants operating on conventional fuels.

Large Power-Consuming Industries

Industries which are large consumers of power, for example the producers of aluminum, magnesium, superphosphate for fertilizer, cement, etc., are today locating plants at sources of low-cost power. These resources of cheap power are of limited extent and at sites which are often far removed from markets for the products. Ultimately these sources will be depleted or saturated at which time the availability of nuclear power will provide a new degree of freedom in determining the most economical location for plants. It is conceivable that cases may arise in which local low-cost fuel resources are exhausted and plant operation could be continued more economically by use of nuclear power at that location rather than by abandoning the existing plant facilities.[43]

Transportation Industries

Of the industries concerned with transportation, the shipping industry has probably the most immediate interest in any development of nuclear power. Although the experimental nuclear power plant proposed for construction would not necessarily pilot the type of plant best suited for shipboard use, the technological information developed would be of considerable interest. The major advantage of nuclear plants over conventional plants to power ships consists in their potential ability to provide essentially unlimited range of operation without the necessity for refueling. The economic significance of this operating flexibility is strongly dependent upon the type of shipping involved.[44] [45]

Inadequacy of Current AEC Projects to Objectives of Proposed Program

There are two major areas of reactor development which are closely related to the objectives of the proposed program:

(*a*) The development of mobile power plants for propulsion of military naval vessels and aircraft.

(*b*) The development of dual-purpose reactors for the production of plutonium for military use and byproduct power for industrial use.

Restatement of Basic Premise of Proposed Program

The second statement (p. 73) raises the question: In what respect will these programs fail to provide the type of engineering and economic information required to satisfy the interests of public and private groups discussed in the preceding pages? Before discussing this question, however, it is desirable to reiterate the fundamental premise on which the proposed program is based. This premise is that, although the technical feasibility of nuclear power has been demonstrated, its development for economic utilization depends upon the focusing of engineering and technical effort along lines to reduce both plant investment and fuel costs. A further corollary is that reliable information on the present status (performance and costs) of nuclear power can only be obtained if effort is applied to the practical design of a plant which is constructed and operated.

Mobile Power Plants for Military Use

The Atomic Energy Commission is sponsoring, with support from the Department of Defense, programs for the development and construction of nuclear-powered submarines and aircraft. Recently the Atomic Energy Commission has announced the award of a contract for "development work on a nuclear power plant suitable for propulsion of large naval vessels such as aircraft carriers * * *." [46] Of these programs, the submarine projects have to date contributed most extensively to the technology on which the feasibility of the program proposed in this prospectus depends. Although the aircraft carrier project is too

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[42] E. W. Morehouse, Walter Seymour, and Philip Sporn, Report to U. S. Atomic Energy Commission by Ad Hoc Advisory Committee on Cooperation Between Electric Power Industry and AEC. March 1951.

[43] Isard & Whitney, Atomic Power—An Economic and Social Analysis, p. 70.

[44] Swords Into Plowshares, by the Student Committee on Atomic Energy, Harvard University Graduate School of Business Administration, Cambridge, Mass., 1951.

[45] The Norwegians are conducting engineering studies of a nuclear-powered commercial vessel and its possible economic application.

[46] Atomic Energy Commission Press Release No. 439, August 1, 1952.

recent to have been able to provide any significant contributions, it can be anticipated that it will prove to be a valuable source of improved technology applicable to the development of economic nuclear power. In comparison, the aircraft propulsion project cannot be expected to contribute as substantially because of the very special nature of its engineering problems.

Interference of Military Requirements with Development of Low Cost Power

However, in spite of the extensive technological contributions of these high-priority programs (the development of new structural materials and coolants, the accumulation of engineering data, the development of new equipment, etc.) the very specific objectives and performance requirements of the mobile power plants both obscure the major problems that must be solved to lower the cost of power from nuclear reactors and provide little incentive to solve them. The military desire performance at almost any expense to satisfy their requirements for strategic and tactical use of the naval vessels and aircraft. Furthermore, these requirements for the power plant must be achieved within the restricting limitations on weight and space imposed by the particular applications. These applications may also preclude the use of certain materials and components which a stationary power plant would be free to use. The military must give special attention to designing its plants to insure against failure in the course of normal operation and to minimize the chance of failure under combat conditions. The premium which is paid for reliability of operation is understandably large.

Mobile Plants as Prototypes for Use on Land

All of these special considerations associated with military mobile power plants result in power plants which are far from representing the lowest cost per kilowatt capacity which might be achieved under less limiting conditions. Thus, the mobile power plants now being developed cannot be considered as prototypes for land-based power plants. It would also be unrealistic to expect that one could readily adapt the military designs to provide an economic design for a stationary plant.

Dual Purpose Plants for Production of Plutonium and Power; Background

The Atomic Energy Commission is engaged in an extensive program for the production of plutonium for the atomic weapons stockpile. The reactors which are currently used, and those under construction, for plutonium production are not designed to convert the thermal energy, which is a byproduct of plutonium production, to electric energy. However, with the recently acquired confidence in the technical feasibility of extracting useful power from nuclear reactors, engineering and economic studies have been made to evaluate the reductions in plutonium production cost that might be achieved by crediting such costs with revenues from the commercial sale of power.

The advantages and disadvantages of such dual-purpose reactors are now being extensively studied by a number of industrial concerns, in cooperation with the Atomic Energy Commission.[47] These studies are being made at the expense of the companies involved.

Dual Purpose Proposals

The basic idea came into public view 2 years ago when Dr. Charles Allen Thomas, President of the Monsanto Chemical Co., proposed that his company be allowed to examine the technical and economic feasibility of financing, constructing, and operating a nuclear power plant. Such a dual-purpose plant would make two products: Plutonium, which would be sold to the Government for atomic weapons, and electricity, which would be sold to industry.

Thus the production of electrical energy would be subsidized by the revenue from the plutonium, to make its cost competitive with the local costs of conventional power.

The over-all feasibility of the dual-purpose idea will depend on the answers to three questions. First, is such an operation technically feasible?

Second, can the economics of the operation, based on a Government price for plutonium, be firmly established, to convince industry that it can go into the program without the possibility of unduly risking large amounts of capital?

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[47] The original four groups are: Monsanto Chemical Co. and Union Electric Co.; Dow Chemical Co. and Detroit Edison Co.; Commonwealth Edison Co. and Public Service Co. of Northern Illinois; Bechtel Corp. and Pacific Gas & Electric Co. (Atomic Energy Commission, Press Releases No. 341, January 28, 1951; No. 373, May 16, 1951.)

Third, can the administrative, legal, and security problems involved be arranged to the satisfaction of both Government and industry?

Results of Private Studies

Last June the first round of studies was completed. The results may be summarized as follows:

There is no question of technical feasibility, but at present there is no inclination in any of the companies to invest its own funds in a nuclear power plant. This reluctance of private capital stems from several uncertainties which make it doubtful that such a venture would be profitable. There are various unknowns with regard to Government policies on plant ownership, patent rights, prices for plutonium, etc., but more important, there is lacking good information on the cost and performance of proposed power reactors.

That Government-subsidized private enterprise in many ways offers a bridge over which nuclear development may gradually move from Federal monopoly to true private enterprise is obvious. What is not so obvious, however, is the relation between the development of dual-purpose reactors, and the development of single purpose reactors to satisfy the more general requirements of immediate industrial opportunities.

There are several aspects of dual-purpose reactors that are in conflict with the objectives of obtaining realistic information on the costs and performance of single purpose reactors.

Conflict of Design

Because of the vital role which plutonium plays in the national-defense program, a dual-purpose plant would have to be designed principally as a plutonium-production plant. The design of the plant would be maximized for plutonium production at the expense of maximum power production, because there are definite design conflicts.

Location of such plants would be severely restricted to conform to defense policies.

In order to avoid excessive losses of the vital plutonium, the fuel elements would have to be discharged long before their value as fuel had been exhausted.

Conflict in Size of Plant

The dual-purpose plants would be quite large installations, and in addition some of their components would need to be over-designed to assure steady use under emergency forced-draft operation.

For practical power purposes, on the other hand, the interest lies in plants of low electric-generating capacity—5,000 to 10,000 kilowatts.

We are interested in plants which can be built in remote areas of the world as well as in populated areas.

We are interested in making the electric power as cheaply as possible today—without subsidy. This means shooting for minimum plant costs—this means designing for maximum use of fuel in the reactor.

Finally, we are interested in gaining experience and confidence in reliability of operation of a plant which could be duplicated and put to practical industrial use.

Why Is There No Adequate Nuclear Power Program?

Preceding paragraphs have attempted to show that: (1) There appears to be a basis for widespread interest among both public and private groups in the early development of a practical nuclear power plant; and (2) present and planned programs in the field of atomic energy are inadequate to provide the desired technological advances. The following paragraphs will discuss the third statement (p. 73) which raises the question: Why has an adequate program not been established?

Expected Sources of Support

It has been customary to look for support for the development of nuclear power both from public agencies and private enterprise. The Atomic Energy Commission is authorized by its enabling act to support research and development activities directed toward the practical utilization of nuclear power. In accordance with the policy set forth in the act, the Atomic Energy Commission has recognized the interests of private industry in this development and has encouraged and invited industrial participation in establishing programs. One expected in 1946 that the Atomic Energy Commission, with nominal support from industry, would devote a large fraction of its program to the development

of commercial uses of nuclear power. What then are the factors which have prevented the realization of a vigorous effort by governmental and industrial groups to attack and solve the problems of producing cheap nuclear power?

Major Factors That Have Influenced Support

There are two major factors. First, the international situation has demanded an almost unprecedented production effort to strengthen the military and to secure the Nation's defense. Second, in the 6 years since the atomic energy law was enacted, the early expectations that large-scale commercial uses of atomic power were not too far distant have been proved unrealistically optimistic. The difficult technical and engineering problems which have been uncovered in this period have shown that an extensive and costly program will be required.

Positions of Atomic Energy Commission and Private Enterprise

It is understandable, therefore, that both the Atomic Energy Commission and industry have felt obliged to revise early estimates of their abilities to support a program for the early development of nuclear power. In regard to industry, the financial risks and legal obstacles are too imposing to attract significant investment of private capital. The AEC now has a unique and vital role to play in the Nation's arms-production program. There are no substitutes in the military arsenal for atomic weapons. Nor are there substitutes for nuclear power plants to provide the military with vessels and aircraft which can perform the desired strategic and tactical missions in time of war. Under these circumstances, therefore, any program for the development of a practical nuclear power plant which could at best perform competitive functions, not unique ones, must assume a position of low priority compared to the extensive and urgent military projects.

Advantage of Broad Support by Diversified Groups

It should be made clear that low priority does not necessarily mean no funds. It does mean, however, that when circumstances demand, a low-priority project will be one of the first to be curtailed or even deferred. New technological developments of military interest are continuously being produced. Moreover, the military needs change and expand. The combination of these results in the necessity for rapid readjustments and sometimes drastic shifts in emphasis of Commission activities. A low military priority program established today, and supported almost entirely with public funds, would have no firm assurance that it would be carried through to completion. However, if such a project derived a significant fraction of its support from private groups, its position would be considerably strengthened and its continuity stabilized.

IV. CONCLUSION

A large part of the present military strength of the free world is represented by this country's stockpile of atomic weapons. The same stockpile represents a potentially significant resource of energy for peaceful applications. We are equipped to use the stockpile for military purposes—we are not similarly equipped to use it for peaceful purposes.

The United States as custodian of this great energy resource has a special responsibility to develop the technology which will put it to practical use. The extent of our responsibility covers the interests of all peoples of the free world. The Atomic Energy Act declares it to be the policy of the people of the United States that—

> "The development and utilization of atomic energy shall * * * be directed toward improving the public welfare, increasing the standard of living, * * * and promoting world peace."

We of all nations of the free world are best equipped with financial and technical resources to accomplish these objectives. It is an opportunity to "return strength for strength." It is an opportunity to establish moral and technical leadership. Our position in the world as a whole would be immeasurably strengthened today were we able to announce significant advances in the development of nuclear power simultaneously with announcements of advances in the development of atomic weapons.

ESTIMATE OF ENERGY RESOURCES IN ECONOMICALLY AVAILABLE URANIUM ASSUMING A REGENERATION FACTOR OF 0.90

(*a*) *Assume* Menke's estimate of 100 million pounds of mineable uranium in the United States.[48]

(*b*) This contains roughly 700,000 pounds of U–235.

(*c*) *Assume* that only 50 percent of the contained U–235 can be economically utilized i. e., 350,000 pounds.

(*d*) This would provide a total of about 10^{12} kw.-hrs. of electric energy.

(*e*) The total electric energy production in the United States in 1950 amounted to about 3.3 by 10^{11} hrs.

(*f*) *Therefore*, 50 percent consumption of the U–235 would provide 100 percent of the 1950 United States production for 3 years, or 10 percent for 30 years, etc.

(*g*) *Now assume* that 90 percent of the U–235 consumed is replaced in the process by production of plutonium.

(*h*) *Further assume* that the plutonium when consumed as fuel also is 90 percent replaced by new plutonium.

(*i*) *Then* the original economically available supply of U–235 (350,000 pounds) provides 10 times as much energy as it contained, namely 10^{12} kw.-hrs.

(*j*) This would provide 100 percent of the 1950 United States production for 30 years.

(*k*) NOTE.—This illustration assumes the ultimate consumption of less than 10 percent of the mineable United States uranium resources. This illustration omits from consideration all economic factors. It is provided merely to indicate the order of magnitude of nuclear energy resources.

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2. PRIVATE INVESTMENT FOR ATOMIC POWER

Murray Joslin, assistant to President, Commonwealth Edison Co. (Chicago)

(Before the Special Conference of the National Industrial Conference Board at the Waldorf-Astoria Hotel in New York City on October 17, 1952)

My presentation will cover a plan we have evolved to enable a privately owned public utility company to proceed with the final design, construction and operation of a dual purpose—power and plutonium—reactor plant, without requiring changes in the existing law and without going beyond its proper sphere as a regulated public utility.

For a clear understanding of the somewhat complex approach necessary to reconcile such a company's obligations under the Atomic Energy Act of 1946 and its obligations to the rate payers who use its service, I shall summarize briefly the status of nuclear power as we find it today—not what that status may be in 1950—X, or in 1960—Y. Because the companies I represent—Commonwealth Edison Co. and Public Service Co. of Northern Illinois—constitute one of the nuclear power study groups working under an agreement with the Atomic Energy Commission, it is important to keep in mind that the views expressed here are our own and not necessarily the views of the Commission:

1. At the present stage of development nuclear fuel, as a fuel, is not competitive with conventional fuels. We do not know how to build a nuclear power plant today which will produce kilowatt-hours cheaper than a coal, oil, or gas-fired power plant of modern design, without crediting the operation with the value of plutonium produced at a price based on its military value rather than on its thermal or fuel value.

2. As might be expected, there are extraordinary risks involved in this new technology. The first power and plutonium reactor plant will be a "model T" compared to those of the future. We should remember, however, that the model T was a pretty good automobile in its day—I understand a few of them are still being operated.

3. As the law now stands, private ownership of a reactor and of its nuclear fuel is effectively prohibited.

4. A large-scale project is probably required to average down the costs sufficiently to achieve economic justification; therefore, a large capital expenditure will have to be made.

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[48] John R. Menke, Nuclear Fission as a Source of Power (Cowles Commission Special Papers No. 1), 1947.

5. A privately owned utility company—the logical agency for bringing private capital to bear on the development of nuclear power—has no venture capital, in the generally accepted sense. In such a company, customers reap the benefits of a successful venture; stockholders suffer the consequences of an unsuccessful one.

Now all this adds up to make a seemingly impossible situation because of the apparently irreconcilable factors that exist under the present state of development of nuclear power and under the law as it now stands. These are the factors which have prompted so many to feel that the only approach for the private investor is to seek changes in the law and that the only approach for the scientist and engineer is to continue research and experimental work and to advocate the building of pilot plants.

On the other hand, it is our feeling that:

1. Someone must build and operate a nuclear power plant; we will never solve the problems by engineering and research alone—we must have actual experience.

2. There are feasible reactor power plant designs which will produce substantial quantities of fissionable material and power.

3. There is a chance that the present cost of plutonium for the military can be reduced by a properly designed dual-purpose plant when such a project is credited with the going value of the electricity produced.

4. Such a project will hasten the day when nuclear fuel may be competitive with other fuels on a peacetime basis because it will furnish the opportunity for developments that can come only through actual experience.

5. Such a project is in the national interest because it should reduce the future cost of national defense—dual purpose reactors are less likely to become "dead facilities" in peacetime than those which throw away the heat. Dual purpose reactors running in peacetime for power production alone are immediately convertible to the dual production of power and of plutonium for the military with no expense of "moth-balling" or retooling.

Now our plan is as follows—and please keep in mind that it is only in the discussion and development stage and has not been submitted to the AEC as a formal proposal:

The reactor power plant would be built on a site acquired by us, suitable for a conventional power plant and connected to our general transmission system. The AEC would pay for and own the reactor proper. We would pay for and own the conventional facilities which obviously would consist of turbo-generators, condensers, switchgear, etc. Certain "intermediate" facilities such as the heat exchangers would be paid for by AEC through a grant in aid of construction.

Our capital investment would be protected against abnormal financial risk in the event we could not use the reactor—for example, if we could not get fuel. This would be accomplished by AEC maintaining with us an adjustable construction grant. The amount of the grant would represent the difference between—

(*a*) Our investment in the facility plus the cost of installing boilers and topping turbines to make it a complete plant, over and above

(*b*) The then cost of building a normal conventional power plant of like capacity.

For example—and the figures are only illustrative:

If our investment less depreciation plus the cost of boiler and topping turbine were	$200
And the cost of a conventional plant of the same capacity were	170
The adjustable construction grant would be	30

AEC would furnish, at its own expense, the necessary fuel elements and would also handle the disposal of the fuel elements after irradiation. We would pay the Government monthly the excess of:

(*a*) The value of the kilowatt-hours received into our system on the basis of comparable costs of kilowatt-hours produced from a modern conventional steam station of corresponding dependability, load factor, etc., over

(*b*) the actual operating and maintenance costs incurred by us in the operation of the station plus taxes, depreciation and return on our investment.

For example—and again the figures serve only to illustrate the mechanics of the plan:

(*a*) The value of power in a given month	$400
(*b*) The sum of operating and maintenance expense and fixed charges on our investment in that month	300
We would pay AEC in that month	100

It will be noted that the entire approach would be to give the Government the benefit of any and all saving, below the cost of conventional power, as a credit to the cost of plutonium. This, of course, is a corollary to the "no financial risk" concept. In this connection, I should say "no abnormal financial risk" because we would have all the risks connected with the conventional facilities employed in the project—which are, themselves, unconventional in many respects—plus a lot of others that we have only a general idea of at this stage of our study—and all this with no opportunity for profit in the accepted business sense.

The outstanding features of our plan, and our hopes for the facility it might bring into being, may be summarized as follows:

1. The plan requires no legislative changes at either the national or the local level.
2. Under it we would invest our funds in the so-called conventional facilities.
3. We would assume all the financial risks that are normal to our business plus a lot of problems that are anything but normal.
4. We would be protected from the abnormal financial risks that we could not rightfully assume as a utility.
5. The facility would be a substantial producer of fissionable material for the military so long as stockpiling is continued.
6. The facility would be a source of income to the Government when stockpiling is discontinued and it is operated for power alone, but of course the Government would bear the cost of fabricated fuel elements.
7. It would be a valuable national defense facility because we would be committed to going on a military plutonium production schedule whenever called upon. As those familiar with the technology know, this can be done on short notice with no unusual expense.
8. The beneficiaries of the project would be:

   (*a*) The country at large for its plutonium production capacity and its contribution to technical knowledge.

   (*b*) The users of electric utility service generally, if it will hasten the day when nuclear fuel can be employed to reduce the cost of producing electricity.

In other words, we believe that such a project should be, in the fullest sense, in the public interest.

APPENDIX B

The following are recent speeches by three AEC Commissioners and one former Commissioner bearing on atomic power problems.

1. THE ATOM IN NATIONAL DEFENSE

Remarks by Gordon Dean, Chairman, United States Atomic Energy Commission, Before the Seventy-fifth Annual Meeting of the American Bar Association, San Francisco, Calif., September 17, 1952

It was a very wise Roman military writer by the name of Flavius Vegetius who stated as long ago as the fourth century that "he who would desire peace should be prepared for war."

It has taken the United States of America a good many decades and two vicious and devastating world wars to learn this basic lesson. But it now appears to be well learned—as witness the 85 percent of the Federal budget that is related in one way or another to the national defense.

If we could sum up in one brief phrase the primary concept behind the current defense program of the United States, I believe it would read, "peace through preparedness."

This is a worthy goal, and it holds out the hope—to our own people and to our friends abroad—that sufficient military strength may be mobilized to stay the hand of a potential aggressor before he strikes the irrevocable blow.

This assumes, of course, that our antagonist, no matter how ruthless he may be, is prudent enough to avoid bringing upon his head the devastation that the irrevocable blow would unleash.

In the case of the Soviet Union, I like to think that there is some basis for this hopeful assumption, for the risks the Russians have taken to date have been well calculated. To me this tends to suggest, I hope not too wishfully, that the prudence of the Soviet leaders is sufficient to temper their ruthlessness when their own personal survival is at stake. This, as I see it, is the world's principal hope for peace—at least until the time when we may succeed in our constant quest for a real, permanent peace, including the effective international control of atomic energy.

Another objective of our defense program—after the preservation of peace—is quite naturally and obviously to achieve victory on the terrible event that another world war is imposed upon us.

There are those who say that it would be hard to distinguish the victor in the event of such a war, and the awful truth is that there is much in what they say. But for those who have enjoyed the right to freedom and personal dignity, as we have, it is hard to imagine anything that would be worse than the loss of these rights.

As I am sure you are well aware, the military products of the national atomic energy program play a very large and important part in the defense effort of the United States. For a number of years they were about all that stood between us and the formidable Soviet military machine. More recently, some of the other sources of our military strength have been bolstered. Our Army has been enlarged, the size of our Navy and Air Force has been increased, our ties with friendly nations have been strengthened, and new and improved tanks, aircraft, guns, and naval vessels have begun to join operational units.

But if anyone concludes that this progress in other defense areas has resulted in any diminution of the importance of the atom in military affairs, he is very badly mistaken.

The atom is still the principal instrument by which we may destroy—or at the very least severely reduce—the ability of an aggressor to make war. And, in addition to this now traditional role, recent technological advancements have begun to find a key place for the atom in the arsenal of the men whose duty it is—if the need arises—to go out to do battle with other men, on the land, on the sea, and in the air.

As a result of this development, the Atomic Energy Commission last spring asked for a special appropriation of nearly $3 billion to increase our capacity to make fissionable material, and therefore our capacity to make weapons. This was over and above the other funds we had already been granted to operate our program as it exists today.

Because it says many of the things I should like to tell this audience, and because it provides some feeling for the considerations that motivate those of us who serve on the Commission, I ask your permission to quote from the statement which I made to the Congress at that time. I quote:

"We are well aware of the fact that this is no ordinary request for funds.

"We know that it involves a very large sum of money—the largest single sum ever requested for the national atomic energy program.

"We know, too, that it involves a very large construction effort that will inevitably make heavy demands upon many critical skills and materials that are in short supply.

"And we know that it comes at a time when other defense expenditures are extremely high. * * *

"And yet we have concluded that this request must be made. As a matter of fact, we strongly believe—on the basis of all the information we have had—that we would be grossly derelict in the discharge of our responsibility if we failed to make it, and if we failed to make it at this time. * * *

"The setting in which this request is made stems from recent revolutionary developments in the field of atomic-weapons technology. Through these developments, the whole concept of how atomic weapons can be utilized in warfare has been radically revised.

"No longer are they looked upon only as devices to be used in a 'Hiroshima type' way against cities and industrial areas. It is now possible to have a complete 'family' of atomic weapons, for use not only by strategic bombers, but also by ground-support aircraft, armies, and navies.

"The Department of Defense is very much aware of this change in concept, and atomic weapons are being incorporated into the operational plans of all three of the armed services.

"This, quite naturally, has greatly increased the demand for atomic weapons—to an entirely different order of magnitude than it was a few years ago.

"It is the purpose of this expansion to meet this new demand, and to meet it as soon as possible.

"We could, of course, meet this demand eventually with the facilities we now have on hand or building. But we would meet it much later. This new expansion is designed to reach the minimum military stockpile requirement at least 4, and possibly 5, years earlier than would otherwise be the case—4 years in which I think we can be sure the Soviet Union will not be idle."

That is the end of the quotation, and it is the burden of the argument upon which we rested our case for funds.

After a dramatic, nonpartisan debate which delayed the adjournment of Congress for several days over the Fourth of July week end, the expansion program was authorized and we were granted the nearly $3 billion we needed to get it started.

I am glad to report to you that this program is already underway and that it is going forward on schedule. It includes, among other things, major additions to our existing plants at Hanford and Oak Ridge, and to our plants now building at Paducah and in South Carolina. It also includes an entirely new billion-dollar plant to be erected near Portsmouth, Ohio.

But one may well ask, "Why the rush? Why all these new plants and great expenditures just to pick up 4 years in time?"

The answer is that as of today neither we nor the Soviet Union has all of the bombs that could be used in the event of an all-out war. If our primary objective is to deter war—and that *is* our primary objective—we must therefore hold on to and if possible increase our atomic leadership over the Soviet Union during this critical period.

Up until 1949 our objective of deterrence was served by the fact that we had a monopoly in the field of atomic weapons. Since 1949 our objective has been served by the fact that we are well ahead of our only hostile competitor.

But I think it is quite obvious that the current atomic arms race cannot go on forever. Somewhere along the line there is a point where the law of diminishing returns begins to operate. And somewhere, not too far beyond this point, there is another point where we will have acquired all of the weapons we would

possibly need to destroy, not only the industrial ability of an aggressor to make war, but also his forces in the field.

When this point is reached, and it is *not* in the *unforeseeable* future, the question arises: "What do we do then?" Do we go on turning out more and more fissionable material and more and more weapons, as we are doing now? Or do we say to ourselves, "Now we have enough; no matter how many bombs our competitor may choose to make, we have enough."

I think we should do the latter. If we some day have enough weapons on hand to destroy completely an enemy's power to make war, does it achieve any more deterrence, or does it enhance our chances of victory in the event of war, to have enough to defeat him and his armies 20 times over? I think not. I think our objective of deterrence, as well as our allied objective of achieving victory, will be served as much as it will ever be served when we have on hand sufficient atomic weapons to defeat an enemy *just once*—and this regardless of the number he may have.

When this point is reached the competition will no longer be simply one of making weapons and weapons material. It will become, instead, mainly one of designing, developing, manufacturing, and training men to use new and effective means for delivering weapons and for preventing their delivery against us and our Armed Forces. What I am talking about here is a competition in the design and development of such items as guided missiles, artillery, supersonic aircraft, electronic devices, radar networks, and the like. This, of course, is mainly the province of Mr. Pace and his colleagues in the other military services, and I am sure that they are doing their utmost to advance as rapidly as possible along these technological fronts.

I hope that no one will receive the impression from these remarks that, as of today, we occupy a position of weakness in the field of atomic weapons. Actually, we occupy a position of great strength—not only on an absolute basis, but also vis-à-vis our principal international competitor.

Conversely, I hope that no one will receive the impression that we are on the verge of acquiring all of the atomic weapons we could use in the event of an all-out war. We are obviously not in that position, for if we were, we would certainly not be undertaking the new, very large expansion program that is now getting under way.

It is the purpose of this expansion program to help us to reach our goal of maximum atomic strength—and to reach it as soon as possible. In this effort, time is clearly of the essence. Thus, if we lose time in pushing it forward, we will be defeating the whole purpose for which it exists.

This means that in the years immediately ahead of us we must lose no time in designing and building these new facilities. We must lose no time through errors in judgment or by letting other objectives of our program stand in the way. We must lose no time through materials shortages, or difficulties in recruitment. And we must lose no time through work stoppages.

We are approaching this expansion program with a strong sense of urgency. Our objective is to get the job done, and to get it done well and fast. In our drive to accomplish this I would like to say quite frankly that we need and greatly desire your understanding support.

There is an old adage which says, "Haste makes waste." We hope to disprove that old adage, but I think any reasonable person will admit that when one makes haste, one is more likely to make mistakes—not necessarily big mistakes, but mistakes just the same.

We hope not to make any mistakes at all, but if we do, this is one place where we could use your understanding support. If you hear of a mistake we have made, I hope you will examine it closely enough to determine whether it is a big or a little mistake—and if it is a little one, I hope you will do us the service of looking at it in the perspective of the great stakes for which we are playing.

As for big mistakes, about all I can say is that we shall do all within our capacity to keep from making any at all.

Much of what I have said up until now in these remarks has been focused on a future point in time when we can stop our urgent drive to make more and more and more atomic weapons, and sit back, look at our stockpile, and say, "Now we have enough."

If we can assume that such a point exists, and I am willing to be numbered among those who say it does, some rather interesting and provocative questions are raised. Not the least of these is the question: "What will happen to the atomic energy program of this country?" Will the plants and laboratories be closed down and moss be allowed to collect on the billion-dollar machinery?

Or is there some other use for these facilities and the people who have been trained to use them? Cannot most, or at least some, of them by utilized for some constructive purpose?

These are important questions, and they have ramifications which radiate backward into the present. For example, they produce, among other things, the hard, persistent, and important current query: "What should we be doing *now* to get ready for the day when we can go out of the bomb business?"

The significance of this question is even further increased by other situations which could conceivably produce an urgent need for an answer. For example, as someone has said, "Suppose peace were to break out tomorrow." This may not be a likely possibility, unfortunately, but it is a possibility nevertheless, and it must be considered.

The obvious answer to nearly all of these questions is to make a determined effort *now* to develop the peaceful uses of atomic energy, of which there are potentially very many. This is the obvious answer to the questions about the future, and it is also an obviously important and desirable effort to be making anyway, for it is the peaceful promise of atomic energy that has captured the hope and the imagination of the peoples of the world—not its awesome power to destroy.

Some may think that mention of these peaceful things is out of order in a discussion of the atom and its place in national defense. I cannot agree. The grand objective of our national-defense program, in which the atom plays such an important role, is to safeguard the national security and the security of our allies *without war*, while the quest for permanent peace goes on. This implies not only a strengthening of our military power in order to deter aggression; it also implies a strengthening of our economy so that our political system will not collapse through economic weakness and lie an easy prey to the predatory forces of communism.

I should like, if I may, to return for a moment to our old Roman friend Vegetius, and venture to suggest that his wise comment on preparedness might be more appropriately tailored to the twentieth century if it were to read, "He who would desire peace should be prepared for *both war and peace.*" And, we might add, he should be prepared for "cold war" as well.

I think it behooves us, therefore, to look rather closely at this thing we have that is called atomic energy, to see just what it might have to offer to improve the health and welfare of both ourselves and our friends and allies in the free world. And I think we should do this, not just because it is the decent and humanitarian thing to do—although this is a very good reason; and not just to find future employment for our atomic energy program; but also because there is every indication that somewhere in the atomic energy package there are things that can give the economy of the free world some of the strength and resiliency it will need to withstand the strains and stresses of a prolonged cold war.

This, we might say, is national defense in its very broadest sense, but it is still national defense, and, to my way of thinking, it is one of the most important parts of the national defense.

Let us look, then, for a moment, into this atomic energy package to see just what there is in it for peace. Such a look today, I believe, would reveal a brighter picture than it would have revealed as recently as a year or even 6 months ago, particularly in the matter of power. While the bombs and the new plants have been building, and the explosions have been going off in Nevada, there has been progress in the quieter corners of the atomic energy program—progress that has breathed the fresh air of new optimism into the hope for real, economic atomic power.

There have been a number of factors which have contributed to this upswing in optimism, and among them I would list these two principal ones:

First, the interest of private industry in atomic energy and particularly the production of power. As many of you doubtless know, we recently had four groups of utility and chemical companies into our program to study the feasibility of economical power production from atomic energy. These groups were greatly interested in the fact that nuclear reactors, in theory, can be built to produce both plutonium and power. Since the Government has a demand for plutonium for atomic bombs, and since private industry has a demand for power for commercial use, the simultaneous production of both has an obvious appeal, especially from the standpoint of costs. These four groups of companies were in our program, with our cooperation, for more than 6 months, and recently they submitted their reports. Not one was pessimistic.

Secondly, as another reason for the current optimism, I would list the technological progress within our program which has recently caused a number of scientists to revise substantially downward their earlier estimates of the cost of building a nuclear reactor to produce power. It has been known all along that a reactor could be built to produce power—as a matter of fact, one of the reactors at our testing station in Idaho actually produced power last winter. But the trouble has been with the cost, which would have been many times higher than the cost of even the most expensive power from other sources.

But most recent experience has shown that there is real hope that these costs can be substantially reduced. This experience has come from the reactors we have recently completed or are now working on. The reactor we are now building to power a submarine is one example of the kind of places where we are picking up knowledge and experience upon which reasonably valid predictions of future costs can be made. There are other examples among the research and developmental reactors we are building.

To illustrate what I mean, let me discuss just one specific example. Recently we completed construction on, and placed into operation, a new reactor which is now working successfully. When this reactor was first thought of, it was believed that it would take $50 million to build it. The actual final construction cost was not $50 million but $20 million, and now I am told by some of our scientists that they feel they could take the lessons learned on that reactor and build a somewhat smaller but essentially similar machine, without the costly research features of the original one, for as little as $5 million and possibly even less.

When you get down into this range, the cost of the power such a machine would produce begins to become interesting—not because it would compete generally with power from coal, oil, gas, and falling water, but rather because it looks like it might begin to become competitive in a few isolated locations where normal power costs are extremely high.

I hope my references to this specific example will not be misunderstood. I am not talking here about the kind of a reactor that would be suitable for a big central power station, feeding kilowatts by the millions into a utility network. That is what the industrial study groups are pursuing. What I am talking about here is a relatively small machine that would produce kilowatts numbered in the thousands, but sufficient to perform a useful purpose in undeveloped or underdeveloped areas which are remote from normal sources of power, and which are now either priced out of the power market or can afford only a marginal supply at best.

In any event, this is an interesting and challenging possibility, and it is a possibility which the Commission is now very seriously looking into.

There are many other examples of the advance that is being made along the road of peaceful atomic energy development. If you have difficulty in accepting this statement, I suggest that you talk to the Wisconsin farmer whose corn yields have been increased because agricultural research with radioisotopes has told him the best time and place to use his fertilizer each year; or to the California oil company that developed a new engine lubricant with the aid of radioisotope research; or to the New York patient whose hyperthyroidism was cured through the administration of radioisotopes.

The horizon of atomic energy is steadily widening, and I am among those who believe that over that horizon there are uses that man has not yet even dreamed of. How many people, for example, when electricity was discovered, could visualize a modern television set? And how many, when crude oil was first found in the earth, could visualize the modern jet airplane? Atomic energy gives every indication of bearing the same rich fruit if we will only devote the time and effort it takes to encourage and stimulate its growth.

In many ways we are today at a crossroads in the peaceful development of atomic energy, and it is encouraging to realize that we have arrived at this point in spite of the heavy-weapons load we carry. I say we are at a crossroads because of the many lines of development which are reaching crucial points almost simultaneously—such as the interest of the military in mobile reactors to power submarines, ships, and aircraft; the interest of industry in the production of central station power concurrently with plutonium; the interest of the scientists in the development of small nuclear power plants; and the intensification of the interest of industry, agriculture, medicine, and science in the utilization of radioisotopes.

There is before the Commission the question of deciding how much attention we can and should devote to these developments in the midst of the current

expansion program and the current atomic arms race. I hold the view that they merit a good deal of attention. I think our atomic enterprise and our country is big enough to accommodate both an atomic energy program for defense and an atomic energy program for peace. And I think we should have both because—if for no other reason—we need the strength and body that atomic energy can lend to the economy and well-being of the free world in its perhaps very long and hard competition with communism.

I think it is fair to say that in general my colleagues on the Atomic Energy Commission share these views.

So we are going to push forward in this field of peaceful uses. We have, of course, the choice of letting them ride along or pushing them. We are going to push them. And in doing so we are inevitably going to push into an area where a whole range of questions of basic public policy must be faced up to and resolved.

Most of these questions revolve around the central fact that today atomic energy in this country is a 100 percent Government monopoly, and it is a monopoly because that is the law of the land. But if the peaceful uses of atomic energy are to be brought to full flower, and find a permanent and secure home in our economy, is it not true that the Government must relinquish at least part of its monopoly? We think it is. But, if so, how much of the monopoly can and should be relinquished? And how can this withdrawal be done neatly and smoothly without disrupting the weapons side of the program and without making room for abuses and inequities? And as it does withdraw, what rights can and should the Government leave behind to protect the over-all public interest?

These are important, basic questions of public policy and they will ultimately have to be answered by the Congress, perhaps by the Congress that will be seated next year.

But the things that we do now, and the thinking that we do now, are vital preliminaries to ultimate action. And since they are public questions, I strongly believe that the public should be thinking seriously about them, for it would be unfortunate indeed if the final judgments were made without the benefit of an enlightened public opinion.

These are some of the things that are occupying our minds today on the Atomic Energy Commission. We wear many hats. A good deal of the time we are occupied by the pressing problems of the moment—the production line, the construction program and the weapons tests. But in the time we have left we must try to be philosophers, economists, and even fortunetellers.

In these many contrasting but related efforts we need your help—not only as informed and understanding citizens, but also as potential recruits for service. No enterprise can be any better than the people who run it, and too often today the Government finds that the most vocal grandstand quarterback resists violently the invitation to come down on the field to play—even when the game is being played for such a vital prize as that of freedom.

I began these remarks with a quotation from a wise Roman military writer of the fourth century. I should like to conclude them with a quotation from a wise military leader of the twentieth century, General Omar Bradley. I quote:

> "Americans guide their Government, and their destiny, through their elected and appointed leaders. Fortunately, there is no dearth of strong leadership in the United States. But many of the great fullbacks and linesmen of American enterprise are still on the bench rather than in the game * * *.
>
> "Unless * * * more strong men drop their briefcases full of contracts to take up the reins of government, we will lose by default in the struggle we are engaged in today. If industrial and labor leaders will step forward and help run our Government in the American way, there will never be a danger of our Government running America in the wrong way."

2. REMARKS PREPARED BY EUGENE M. ZUCKERT, MEMBER, UNITED STATES ATOMIC ENERGY COMMISSION, FOR DELIVERY BEFORE THE CHICAGO SECTION OF THE AMERICAN CHEMICAL SOCIETY ON THE OCCASION OF THEIR ATOMIC ENERGY DAY, AT THE COLISEUM, CHICAGO, ILL., SEPTEMBER 11, 1952

I welcome the opportunity to speak at your Atomic Energy Day. This Seventh National Chemical Exposition is indeed inspiring and is a tribute to the ability and ingenuity of American chemists and chemical engineers. The growth of the American Chemical Society over the years is symbolic of the spread and growth of chemistry's contribution to modern life.

It is fitting that this milestone of science and engineering, commemorated in Chicago, should feature the progress and uses of atomic energy. It is a little startling, perhaps, to realize that only 10 years ago, in this very city, man first initiated a self-sustaining nuclear chain reaction, and controlled it. The anniversary date will be December 2—only 10 years away as the calendar measures time, but eons away in terms of atomic progress.

Because laws of physics govern the operation of chain reactors and nuclear weapons, it sometimes seems that atomic energy is the private preserve of the physicist. But the advances would never have been possible without the work of other groups of scientists and engineers, especially the chemist and the chemical engineer. It was the chemist who, during the Manhattan District days, developed a suitable method for the separation of plutonium from irradiated uranium and its attendant fission products. Throughout these past 10 years more and more importance has attended the work of the chemists in all phases of the atom business—from ore refining to the finished products, uranium 235 and plutonium in bomb shapes or reactor fuel elements and radio-isotopes. And, according to what my scientific and engineering colleagues tell me, future progress will depend, to a very large extent—yes, to an ever-increasing extent—on chemistry.

Now, I'm not a chemist and I'm not an engineer. You might call me a "civilian member" of the Atomic Energy Commission. Hence I rely on the technical experts at the Commission who tell me that even greater challenges face the chemists in the atomic-energy program of the future than they have met in the past. These are problems which you must solve if atomic energy is to move forward at the rapid pace it has set for itself since 1942.

For example, these scientists point out that the future of peacetime nuclear power will depend upon the development of successful breeding cycles. These will enable us to utilize relatively abundant U–238 and thorium for the release of nuclear energy, in addition to the much rarer U–235. The chemist will be called upon to play a key role in this development.

They tell me, too, of other technical problems. Figuratively learned doctors crowded my office before I came out here, outlining problems which I might lay before you, but I am just relating a few today. One of these concerns radiation chemistry. There is much in this field to be explored before university and industrial laboratories can begin to appreciate the potentialities of this phenomenon in effecting unusual and valuable reactions. Perhaps radiations can be used to simplify and lower the cost of key reactions used in today's chemical industries; perhaps they can make possible new reactions on which you can build new industries.

The hallmark for purity in atomic matter is not that well-advertised 99 and $^{44}/_{100}$ths percent purity—it is much, much closer to 100 percent. Your colleagues working in this field, as you know, must worry about parts per million, and occasionally even parts per billion. The challenge of working to such degrees of refinement is one that must be met every day.

Let me list briefly some more problems: The disposal of radioactive wastes economically and without hazard to environment, the concentration of waste fission products to reduce the volume that must be handled, the separation and packaging of fission products on an economic basis for uses being developed, the separation of isotopes by chemical means, and—not to be overlooked—the need for a better understanding of the effects of radiation on living cells. The gross biological effects are well known. However, the chemical reactions responsible for these effects are as yet largely unexplained.

These problems illustrate the vital role of the chemist and the chemical engineer. In addition to technical problems, the future—indeed, the ever-nearing future—is bringing us the necessity for making a series of important decisions.

Because of international conditions, the great bulk of the atomic-energy effort has been, and is now, aimed at the goal of achieving military strength to help insure world peace. That is why the atomic-energy program was originally conceived. And in the short time of less than 10 years we have—instead of just one atomic weapon—a family of weapons in an ever-increasing stockpile.

However, the Atomic Energy Act foresaw other uses for atomic energy. The act looked toward the field of civilian applications; and, with the late Senator Brien McMahon's foresight and vision setting the pace, it looked toward the field of civilian power. Even as early as 1946 the addresses of one of your distinguished associates, Dr. Charles A. Thomas, the president of the Monsanto Chemical Co., prophetically looked toward the day of harnessing atomic energy for power.

DEVELOPMENTS LEADING TO USEFUL NUCLEAR POWER

As we have noted, the emphasis in the atomic-energy program has been on applications for national security with the consequent subordination of civilian uses such as power. Another factor which has seemed to lessen the emphasis on the power field is our country's comparatively bountiful supply of low-cost conventional fossil fuels.

But now, even in the 6 months I have been with the Commission, there is a noticeable quickening of interest in atomic power. Useful power from nuclear energy seems to be much closer to us than it was 6 months ago. One of the reasons for this is that the AEC has had four groups of companies, including the Dow and Monsanto Chemical Cos., looking into the possibilities. Yes, you can feel the increasing interest in atomic power, and get the strong hope that it really may be closer. The growing interest includes the practicality of atomic power for the opening up of underdeveloped areas, both in this country and in other parts of the world.

It is heartening to note the action of the four groups of utilities and industrial concerns as they indicate their desire and willingness to invest their time, talent, and money in preliminary and design studies. It is essential that the Atomic Energy Commission use every reasonable means at its command to assist these efforts. We hope, and have every reason to believe, that something other than a request from industry for a complete subsidy of engineering design and construction will result ultimately from these and other similar studies.

Indeed, we expect confidently that these representatives of American industry will join with us in finding the key to unlock the door to the future in this challenging field. We on the Commission know of no effective substitute for the pressures of competition in any area where imaginative and daring attacks are required to get a solution to a problem of such magnitude.

Scientists had thought of atomic power as being economically practical 10 or 15 years hence. We suddenly find that this may not be the situation, for power from atomic energy seems closer at hand. I am not one to name a date, but I will say that we will have one, or perhaps a few, nuclear power plants producing electricity for industry or central-station networks sooner than the 10- or 15-year period we had been estimating a short while ago.

Already one example of atomic power is an actuality. Last December, AEC's experimental breeder reactor in Idaho produced, as one of its first acts—although admittedly a secondary act—an experimental amount of power.

The progress that has been achieved to date in Commission activities in support of military requirements for mobile reactors to power ships and planes has been made available to the industrial groups for study. The combination of scientific and management brains exploring the problem has been excited by the possibilities and the apparent ability to overcome the technical problems.

This does not mean the immediate attainment of nuclear power. There is a second phase still to be worked through before even the design of a power reactor becomes available. Then, of course, must come the building of such a reactor, and the inevitable "shake-down." For some time, therefore, it appears that the applications of nuclear energy to power will be limited to pilot plant and prototype operations.

However, this cautious approach is not intended to imply in any way that we should not be actively exploring for solutions to the problems involved. I can assure you that the Commission is presently actively examining these problems, trying to bring to bear in objective fashion the measure of vision necessary to foresee the implications of this development.

There are some who urge that the problem is really quite simple. Their argument is, in effect, that all the United States needs to do is to change the

Atomic Energy Act so that the restrictions on the private ownership of reactors and the private acquisition of patent rights are lifted. Then, the argument runs, industry will really go to town.

Because the Commission is in the process of considering this problem, I am not prepared to give detailed answers. I will state, however, that the belief that the answer lies in action by Congress changing the law to lift patent and ownership restrictions seems to me an oversimplification. Naturally, the effects of the present restrictions are a part of the present picture. But exclusive consideration of them fails to take into account issues inherent in atomic energy itself and in its primary role as a vital element of the Nation's defense policy.

The solutions call for the highest order of vision and statesmanship. If industry is to be able to carry the ball successfully, there must come into being a new and unique pattern of cooperation between business and Government. The delineation of responsibilities at the outset is of the greatest importance in shaping future courses and determining our success in making the most of the benefits of atomic energy in our national life.

POLICY PROBLEMS IN DEVELOPMENT OF CIVILIAN NUCLEAR POWER

I would like to mention some of the questions that seem to demand deep and farsighted consideration.

But first, let me call your attention to two short quotations from the Senate committee report which recommended the Atomic Energy Commission organization. This report was approved by all members of the committee, by both the conservative members of the committee and the liberal members. The first quotation: "From the start of its deliberations, the committee has been convinced that an absolute Government monopoly of production of fissionable materials is indispensable to effective domestic control of atomic energy."

And the second quotation: "The production of fissionable material is technologically in its infancy; unforeseen and unforeseeable factors may play a great part in its development. To permit decontrol or decentralization of this activity, and weaken continuing Government supervision, would be contrary to the principle of prudent stewardship demanded of the Government of considerations of national defense and national welfare."

Thus we see the intent, expressed in 1946, behind the present Atomic Energy Act. That, of course, could be changed. Section 7 (b) of the act envisions this. It provides for a broad-scale review of the social, political, economic, and international effects of atomic energy used for industrial or commercial purposes. *But what can the present intent be changed to?* This question brings us squarely up against a whole range of problems, and so demonstrates that there is more to a thorough solution than a simple change in the wording of the act.

The Commission is now studying these problems. We want—yes, we *need*—the help and advice of industry, for the problems we face are the problems industry faces. They will affect the country s whole social and economic structure. They are so vital that they should be laid out so that all of us—at the Commission, in industry, in Congress, and on public forums—will have ample opportunity to study them and attempt to fit the answers together. Let us examine some of these questions.

The first and foremost question is: *How do we tie in civilian power with national defense?* The requirement of national defense is always the first consideration at the Commission. It is the reason for the extensive development of atomic energy today. Had there been no World War II, no need for advanced weapons, the progress made during the last 10 years might have been achieved only in small measure.

We must determine the effect of any atomic power development on our military needs. *Does the development of atomic power collide with or is it consistent with the Nation's needs for the common defense and security in the broadest sense?* This is a question with many facets. For example: *Will developing civilian atomic power divert more fissionable material than prudent from military uses, that is, from use as bombs and as submarine and aircraft fuel?* And: *Can an atomic plant be built to contribute to both civilian and military objectives?*

The question that logically follows is: *What about plutonium?* This question and its answer tie in closely with the problem of foreseeing military requirements.

At the present time we are thinking of atomic power as being the coproduct of plutonium, both coming from atomic reactions taking place in uranium, con-

verting part of it to plutonium, and releasing heat which could be used in generating electric power. All of us know that the chain reaction in uranium in a large reactor sets up radioactivity equivalent to that which would come from millions of pounds of radium, and that enough heat is released to supply a considerable city with electricity if it could be harnessed economically.

If atomic power is to be provided by coproduct, or dual-purpose reactors, the role of the Government in buying the plutonium produced will have much to do with success in turning out power at a reasonable cost. Unless the Government buys plutonium at prices equivalent to its own production costs, at this stage of development the cost of generating the power might be so prohibitive that no commercial firm would undertake such a project. In other words, the per kilowatt-hour cost to the consumer of electricity from nuclear fuel might keep it from competing with electricity from conventional fuels.

For such coproduct production, the feasibility of industry undertaking a greater role in power development might depend on the assurance the AEC can give of a guaranteed market for plutonium during the next 10, 15, or 20 years. Before private investment could be attracted to this field, assurance—based on sound contracts—would have to be furnished that the Government would continue to need plutonium.

Such a long-range buying plan should also consider the interest of the taxpayer and fairness to all companies concerned. If the military and civilian uses of plutonium enable us to give only a limited guarantee for a period of years, *there would be the question of whether we would be justified in buying plutonium for stockpiling beyond our needs, foreseeable at the time.* Or, the result might be that the number of participants in the program must be sharply limited, *presenting the problem of how to select companies which would be allowed into the circle.*

The problem of purchasing plutonium carries along a companion problem—that of the pricing formula. The price formula should certainly provide a profit incentive covering the entire operation, that is, it should take into account both the plutonium and the power sold as a package on which the seller could make a profit. *But how would the price be worked out to assure adequate incentive without entailing unjustified subsidy of atomic power? Can a system of competition among interested companies be fashioned to strike the appropriate balance of these factors?*

There is another possibility. If the day should come, which all of us—no matter how doubting we might be—fervently hope will come, when world peace is a reality, when international control of atomic weapons succeeds, or at least, when international conditions are more tranquil than they are today, *would there be a need for the Government to continue buying plutonium?*

If the buying of plutonium were stopped, it is easy to imagine the dislocation to civilian industries that would have sprung up around reactor sites to utilize atomic power. With a sudden stop order on plutonium buying, and the resultant sharp increase in the cost of power, *what means could be devised to avoid or minimize dislocations?*

It may be that such problems as these I have been talking about concerning plutonium will never have to be solved. We may hit upon the development of power at competitive cost from non-plutonium-producing reactors, though now it appears that this day is not quite at hand. The first step may be non-plutonium-producing power reactors for remote, power-starved areas. Study of the development of atomic energy from 1942 leads me to feel that the strides the engineers and scientists are making are so great that "power only" reactors may be nearer than we dare hope for, even though we are still in the early phases of research and development.

Regardless of the type of reactor that furnishes the power, we will still need answers to a number of other questions.

One of these questions, or problems, concerns the location of plants. Because of the inherently dangerous characteristics of reactors and the responsibilities for public health and safety they impose, this has been one of the major problems facing the Commission. We have spent almost unbelievable time, money, and manpower on the location of our atomic plants. At the present time we are vigorously studying ways and means of getting built-in safety into reactors and of "containing" possible accidents, in order that the Commission's external safety criteria can be less stringent.

The fact is that not one reactor has yet blown up; and we do not expect any to blow up. We are sometimes thought to be too conservative in locating plants because we will not extrapolate on the basis of experiments. I can

only say that extrapolation, when hundreds and even thousands of lives may be involved, seems to us a slim reed to lean upon. Our attitude must be one of progress with caution.

It is easy to see how the location of the reactors can influence the cost and availability of atomic power. The problem is to determine the responsibility of the Government for establishing criteria governing the locating of privately operated nuclear power plants, and also to determine the methods of executing these responsibilities. We are utilizing the advice of industrial people, who have dealt with problems of industrial safety in hazardous industries for many years. Their findings, along with those of the scientists who make up AEC's Reactor Safeguard Committee, will play a major part in suggesting a solution.

Another question is: *What should be the Government's responsibility for health and safety within privately operated atomic plants?* The problem of protecting the health of the worker in our plants is a constant concern to the Commission and certainly must be to contractors operating power reactors. *What should be done by both the AEC and the plant operators to discharge the responsibilities that arise out of the lethal potentialities of radioactivity?* There will be such practical problems as the type of insurance which private companies would need, both health and compensation, for the protection of themselves and their workers. The Atomic Energy Commission goes to great effort and expense to protect those who work in the industry. *Would private industry be able to devote as much attention to these problems?*

The problem of security is always with us, and will be of particular concern when the power reactor also produces plutonium. Like other problems mentioned, this one is many-sided. You can imagine many of the considerations not applying to other industry that security brings into the picture; I shall mention a few.

Undoubtedly, reactors for producing atomic power will incorporate the latest and best technology. Therefore, unless we have a world of peace, these reactors will be prize targets for espionage and sabotage by unfriendly nations. In addition to protection of the reactor itself, there must be adequate control of the fissionable material produced because of its usefulness for weapons. The Government now spends large sums of money to guard fissionable material and to protect its atomic plants against the leaking of secret information and against sabotage and destruction. *What arrangements could be established to assure adequate protection of private atomic plants in the interest of the national security?*

In the broad sense of security, the Government takes special care to assure continuity of operations in its atomic plants. *What provisions can be adopted to assure such continuity in the private plants? For example, would a special labor-management undertaking be needed?* We must determine the extent to which the Government should be responsible for plant security, even in private plants, in order that national security be protected.

Consider the problem of the security of workers. *What provisions can be made to assure that only loyal and reliable employees have access to secret work in private industry's atomic plants?* We would not expect the FBI, for example, to turn over its reports to private corporations. *How are we to handle the problem of the determination of individuals as good security risks?* Such problems of security, so closely related to national defense, clearly call for the careful spelling out of a partnership between industry and the Government.

One big problem, with its several corollary problems, remains. It relates to the stake of the taxpayer in atomic energy.

With almost $10 billion of their money, the American people have built up a gigantic publicly owned industry. At the present time these taxpayers, through their Defense Department, are also the biggest customers of this industry. When we consider the coming of civilian nuclear power, *what are the rights of the people (the taxpayers) as original stockholders, and what are the rights of private enterprise, upon which our whole economy is built?*

Perhaps, next to that concerning security, the fundamental question is: *How are incentives to be provided for private industry with full recognition of the stake of the taxpayers in the atomic energy activities they have sponsored?*

Of course, amendment of the present restrictions on private ownership of reactor facilities and the establishment of equitable patent arrangements are inevitable if private enterprise is to be attracted.

Under our profit system, when private industry carries the ball it must be able to obtain capital for atomic energy on a competitive basis with other invest-

ment opportunities. This is a competition that becomes of increasing importance as industry opens up more and more attractive avenues of possible endeavor. This applies with equal force both to the actual operators of nuclear power plants and to the army of manufacturers necessary for designing and fabricating the components of the plants.

In other words, patent and property provisions must be drawn in such a way that there can be a profit, a competitively attractive profit. In the same pattern, there must be engineering competition between private companies so that industry will make maximum contribution to nuclear power development. It is this competition which will most effectively drive down costs and bring technological advance.

Yet, we must not forget that the atomic energy industry is unique in the history of our industries. Every step—research, development, and production—has been paid for with taxpayers' money; every cent of the cost of the vast capital structure underlying atomic energy has come from the same source.

There can be no doubt of the stake of the taxpayer in patents developed as the result of cost-reimbursement-type contracts at Government expense. The question that arises is: *At what stage in the cooperative development of atomic power does the private company begin to acquire rights? How do we insure equitable access to the know-how, developed at Government expense, which must be the background for many patent developments?*

There is another factor which requires consideration of how to meet the obligation to the taxpayer. The cost of atomic energy research is so expensive that it is inconceivable that industry could support the research program necessary to achieve continuing progress in the shortest possible time. Here, again, in view of the inextricable relationship between national security and atomic energy, we must ask: *What must we do to protect the national security? Has Government a continuing obligation to assure that broad research activities in the nuclear field are continued at a satisfactory level?*

Finally, and of great importance, is the fact that this new source of energy is one of our great natural resources. *As the custodian, the Government has a special responsibility, in the words of the Atomic Energy Act, for "the development and utilization of atomic energy toward improving public welfare, and increasing the standard of living." What mechanics are needed to insure that the Government will be sufficiently knowledgeable and capable to carry out that responsibility?*

SUMMARY AND CONCLUSION

In summary, I have endeavored to state some of the problems that must be solved before private industry is likely to be able to enter competitively into the field of developing, building, and operating nuclear power plants. First, there was the problem of changes in law. Then comes the broad question of the compatibility of civilian power and national defense. Is there enough fissionable material for both uses? And what about dual-purpose reactors producing both electric power and plutonium as coproducts?

I asked you to think about the problem of reactor safety and location and of the health of workers and of people living nearby in private versus Government operation. Then we considered security for national defense under both forms of operation. Finally, we saw that intimately associated with the stake of the taxpayer in atomic energy are questions of patent rights, profits, competition, research essential for national security, and maximum development for the public welfare.

These are some of the problems as I see them as a member of the Atomic Energy Commission.

All of us at the Commission are receptive to any solutions that would give private industry the most active stake possible in this program.

At the same time we cannot close our eyes to the far-reaching significance of the problems which confront us. Every one of the questions which stand before us should receive full, careful, and intelligent consideration; and the interest of the American taxpayer—the initial investor in the atomic-energy industry—should always receive first consideration.

There is more to this problem than a change in the basic law controlling the development of atomic energy. Changes in the social order possible as a result of atomic energy are not made in the abstract. Industry cannot sit idly by, hoping that the way will be paved.

Certainly, no company should endanger its solvency; but I am sure that industry is not going to sit on its hands waiting for answers. As the oppor-

tunities arise, private enterprise will devote talent and money with normal American spirit to the objective of catalyzing the process of reaching the answers and attaining leadership in this great new field for enterprise.

We on the Commission are keenly aware that it is our duty to make our greatest possible contribution to solving questions such as those outlined here tonight. But we cannot, we are not expected as stewards over the public enterprise, to arrive at, much less to effectuate, the answers. The whole people are the ultimate competent authority. Upon answers made depends much of the progress and breadth of usefulness of atomic energy. All of us will do well to ponder the issues.

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3. PRESENT AND FUTURE ACTIVITIES OF THE UNITED STATES ATOMIC ENERGY COMMISSION AS THEY AFFECT MINING

Remarks Prepared by Henry D. Smyth, Member, United States Atomic Energy Commission, for Delivery Before the Western Division of the American Mining Congress, at Denver, Colo., September 25, 1952.

INTRODUCTION

As a member of the Atomic Energy Commission, I have been invited to speak to this meeting of the American Mining Congress on our atomic energy program. I would like to outline for you the present state of the program and then explain in some detail the problems still before us, with particular emphasis on the future of uranium as a source of energy.

It is perhaps appropriate that I, as the only scientist among the five Commissioners, should discuss atomic energy here in Colorado with a group of mining men, for in a sense we began this thing together. Carnotite from the Colorado Plateau was one of the two major sources of ore used by Mme. Curie and others in their early studies of radioactivity. And this discovery of the radioactivity of uranium in 1895 was one of the principal factors in the extraordinary development of physics and chemistry for the next 50 years. From the mining point of view, the amounts of material used in these early experiments were trivial, but from the scientific point of view the properties of these minerals opened a new world.

RADIOACTIVITY A NEW WORLD

I would like to take a moment here to explain why this new world of radioactivity is, for the scientist, a totally different world from any he has known before. Very early in the study of uranium and radium, it became apparent that the amounts of energy released in radioactive transformations were much larger than in any of the familiar processes of chemistry. I mean, of course, the energy released per atom, because in those days there was never enough material available to make the aggregate of energy released of practical interest. It was apparent that the radioactive disintegration of a radium or uranium atom was a much more deep-seated and violent reaction than any chemical reaction previously observed in nature or in the laboratory.

Gradually, the reasons for this difference became clear. The study of atomic structure showed that all atoms had tiny, heavy central cores which we called nuclei and that these nuclei were surrounded by electrons moving around them rather like planets around the sun. We found that all chemical reactions, even the most violent, resulted only in minor rearrangements of the outermost planetary electrons. But then we found that radioactive transformations came from fundamental changes in the nucleus, the heart of the whole structure. From the scientific point of view, it was interesting to know there was such a thing as a nucleus and that one of its remarkable properties was that it occasionally rearranged itself, giving off a lot of energy. But in those early days this wasn't very exciting from the practical point of view. The nuclei of only a very few elements had this property. These radioactive elements were either very rare or, like uranium and thorium, very rarely disintegrated. And there did not seem to be anything to do about it. All kinds of efforts to speed up radioactive disintegration failed.

Over a period of 20 years, from 1919 to 1939, we gradually came to learn more through the research of scientists in many countries. First it was found that particles shot out by disintegrating nuclei could knock pieces out of other nuclei;

then it was found possible to do the same thing with parties produced and speeded up in laboratory machines such as cyclotrons. Finally, in 1939, nuclear fission was discovered.

The essential point about all this research was that it taught us nuclear processes are totally different from chemical processes. The whole natural world in which man has evolved, indeed life itself, is governed by the laws of *chemical* change. The use of fire in prehistoric time was the first deliberate application of a chemical process for man's benefit. Man has always had the raw data of chemical reactions available for his study when he got around to it. Chemical reactions were occurring every time he drew a breath or ate a meal. To be sure, he began to understand these data only when he added experiment to observation. But just the same, the chemical reactions were there as data all around him in nature.

There are no nuclear reactions in our ordinary environment. No primitive man ever warmed himself by a nuclear reactor. There was, therefore, no background of empirical experience. Remember that only 57 years have passed since the first observation in 1895 of a nuclear disintegration, and that only 10 years have passed since the first self-propagating nuclear chain reaction was achieved at Chicago on December 2, 1942. If you will compare that first nuclear chain reaction in 1942 with the first time primitive man built a fire and controlled it by adding either wood or water, you will realize what I mean when I say that we still know very little about this business. We have put nuclear fission to use but we still do not understand why it works.

To a little uranium ore and no knowledge in 1895, we have added some knowledge painfully acquired over half a century, and have asked for more ore. Then suddenly within the space of 10 years, we find ourselves in this country with a multi-billion-dollar industry based on atomic energy. The future development of this great industry is going to require more and more uranium and, certainly, more and more scientific knowledge.

PRESENT STATE OF AEC PROGRAM

As you all know, the reason we have a multi-billion-dollar atomic energy industry today has little to do with the normal peacetime growth of a new technology. Our plants exist because they can produce a very concentrated and powerful explosive at relatively low cost. No one is glad that the first use made of this great discovery was for military purposes. In this country we want peace. But we have learned by bitter experience that peace is not maintained by wishing for it. To avert war we must be armed. For the 6 years of its existence, the primary purpose of the Atomic Energy Commission has been to help build the military strength of this country to such a point that no enemy will dare attack us or our friends. This is still our principal purpose.

Atomic weapons have been used only twice in actual warfare, on two cities in Japan at the end of World War II. It takes time to develop a new weapon in various forms, and to study how it can be used. Since 1945, the Commission laboratory at Los Alamos, N. Mex., has made great advances in weapon design so that we can now use fissionable material much more efficiently than in 1945 and can make a variety of atomic weapons to meet varying military needs. At the same time, the Department of Defense has had time to explore the most effective way of using the weapons we make for them, and has consequently enlarged its requirements. These two developments, coupled with the increasing international tension, have led the Congress to authorize two major expansions in our plant facilities.

Plants at Savannah River in South Carolina, and at Paducah, Ky., are the biggest items in the first of these expansions. The construction of these new plants is well under way. The more recent expansion, authorized by Congress in the summer of 1952, will cost about $3 billion and give us an entirely new plant at Portsmouth, Ohio, and enlargements of several of our older plants. When this expansion is finished our capital investment in plant facilities will be nearly $10 billion.

Obviously we cannot run all these new plants without increasing our supply of raw materials. To make more atomic weapons, we must have more uranium ore. Thanks to the cooperation of men like you and your colleagues all over the free world we are getting it. Not getting so much of it that we can relax our efforts. Not getting it so easily that we run no risk of idle plants. But at least we are developing good enough prospects to justify our expansion program.

SOURCES OF ORE

I wish I could give you actual figures on all our sources of uranium ore, but obviously I cannot do so without giving data that might be valuable to an enemy. I will have to limit myself to a general description of old and new sources.

As you know, the original sources of uranium and radium were principally the Colorado Plateau and the Joachimsthal in Czechoslovakia. Before the war, both of these sources had been outdone by new mines in the Belgian Congo and in northern Canada. In the past 5 years the Atomic Energy Commission has made intensive search for new sources of supply. Considerable success has been achieved by the hard and imaginative work of our Raw Materials Division under the leadership of Mr. Jesse Johnson. But there have been no bonanzas.

Probably the most striking success in terms of percentage increase in yield has been on the Colorado Plateau. Intensive explortation has greatly extended the area in which uranium ore is believed to occur, and more mines and mills have been opened. We are counting on a continuing flow of ore from this region.

The Belgian Congo mines and Eldorado at Great Bear Lake in Canada continue to be major suppliers. We have high hopes for the new mines in northern Saskatchewan and in Australia. Within a few months we will begin to get uranium as a byproduct from the South African gold mines. A similar source, on a smaller scale, is uranium as a byproduct of the phosphate industry.

These last two sources, the gold ores and the phosphates, illustrate the importance of research in processing. We have known for some time that there was a little uranium in these materials, but it has taken time to develop methods of getting it out. We know of other low-grade sources, but so far the estimated cost of extracting uranium from them is beyond all reason. We wish the mining fraternity would either find some Shinkolobwe in this country or invent cheap extraction processes for low-grade ore. We would not complain if you did both.

FUTURE NEED FOR URANIUM FOR MILITARY PURPOSES

As citizens, you naturally ask how long we are going to continue to spend billions of dollars for atomic armament and when can we use uranium as a source of peacetime power. As mining men, you want to know how long the need for uranium ore will persist, either for armament or power purposes.

These are reasonable and thoughtful questions. Unfortunately, no one knows the answers to them. All we can do is to make guesses on the basis of such facts as we have. Let me report some of these facts. Then you can make your own estimate, or at least judge the validity of mine.

The principal fact about weapons that bears on future needs is the long-lasting quality of nuclear explosives. The plutonium and uranium 235 that we want for weapons do not deteriorate appreciably with time. If we succeed in avoiding war, there must come a time when even the most pessimistic of our military advisers will say we have a large enough stockpile.

As everyone knows, we are now building an atomic-powered submarine. If it is successful, there may be a continuing demand for uranium to fuel naval vessels. The same need may develop for aircraft. But either for ships or aircraft, it is hard to imagine a demand comparable to that required for actual weapons.

URANIUM FOR INDUSTRIAL POWER—FUNDAMENTAL QUESTION

Looking toward power for industrial use, there are many technical and economic questions that must be settled. The most fundamental one is: *Can we use the nuclear energy inherent in both uranium isotopes?* At present we use only the uranium 235 isotope and not the much more abundant uranium 238 with which it is mixed in natural uranium. To understand this point, and others bearing on power production, let me review what happens in nuclear reactors.

How do we get energy from uranium 235? The nucleus of an uranium atom is made up of tiny particles called protons and neutrons. If this assemblage is struck by a neutron under certain conditions, it breaks apart as a result of the impact. This is the process we call nuclear fission. It has two essential characteristics. First, this splitting is accompanied by the release of an enormous amount of energy. Second, it is accompanied by the ejection of several secondary neutrons. The release of energy is what we are after, but the secondary neutrons are needed to maintain a chain reaction. In other words, one neutron enters the uranium 235, splits one atom, and releases energy and several

neutrons. The secondary neutrons enter adjacent atoms, produce more energy, and more neutrons, and so on.

I have implied that this process of nuclear fission occurs only in uranium 235. This is not true. Under certain conditions it also occurs in uranium 238, which constitutes the bulk of natural uranium. Unfortunately, the conditions under which fission occurs in uranium 238 are not readily produced or controlled. The process does occur in plutonium under controllable conditions, but plutonium does not exist in nature. However, plutonium can be produced from uranium 238 by bombarding it with neutrons.

Evidently the simplest way to get energy from uranium is to use uranium 235. it does occur in nature and the conditions required to make it fissionable are not impossibly difficult. It can be used either in its natural mixture with uranium 238 or it can be more readily used, either explosively or under control, after separation from uranium 238. If, however, we could find some way of also using uranium 238, we would increase the usable energy per pound of ore by a factor of 140. The direct use of uranium 238 does not appear feasible at present, but its indirect use through the manufacture of plutonium is possible.

Although we have manufactured many kilograms of plutonium as an atomic explosive we have yet to achieve any economy by doing so. Unfortunately, we need neutrons to produce plutonium and uranium 238. We produce these neutrons by causing fission in uranium 235. This sounds like robbing Peter to pay Paul, but it is not quite that bad. Even if we produce only one atom of plutonium for every atom of uranium 235 that disappears, we have all the energy of the uranium 235 fission as a byproduct. In other words, we end up with just as much fissionable fuel as we started with but have produced a lot of energy.

In principle, it is possible to produce more atoms of plutonium than we burn of uranium 235. There are enough neutrons given off in fission of uranium 235 to make more than one atom of plutonium. The technical problem of actually building a nuclear reactor in which more atoms of plutonium are produced than there are atoms of uranium 235 burned is an extremely difficult one. The excess of neutrons present is very slight, and any failure to utilize them fully will cut down the amount of plutonium produced. Nevertheless, we are working hard on this problem and it is the hope of success that leads us to talk about breeder reactors, because we call this process of making more fuel than is burned a breeding process. A breeder reactor is not getting something from nothing; it is converting uranium 238 into a more usable form of nuclear fuel, i. e., plutonium.

We see, therefore, that we have one primary raw material necessary for nuclear energy, uranium 235; and a secondary raw material, uranium 238. (Thorium is another secondary raw material that I have not discussed.) Since uranium 235 and uranium 238 are isotopes of the same chemical element, they are found together in nature in the constant ratio of 1 to 140. So far as the mining problem is concerned, all we ask of you is to get us uranium. If we need to separate the isotopes one from another, that is our problem.

PRESENT USE OF URANIUM AND ITS LIMITATIONS

All this talk of fission and neutrons and breeding sounds fine. If it is so simple, why aren't we getting power now? Before answering that let me say what we *are* doing now.

What does the Atomic Energy Commission do with the uranium ore we buy from the Colorado Plateau, from Canada, from the Belgian Congo, or from other sources? First of all, we refine the ore. Then the refined product is divided into two streams. One is converted into uranium hexafluoride and goes to the isotope-separation plant at Oak Ridge. The other is converted into metallic uranium and goes to the plutonium plant at Hanford. These conversion processes are complicated and costly but not particularly novel in kind.

The Oak Ridge plant is entirely novel in character, since no separation of isotopes on an industrial scale had ever been achieved before it was built. I will not describe the process but merely remind you that the product of the process is uranium 235.

Once we have obtained uranium 235, we fabricate most of it into parts for atomic bombs. We use some of it as atomic fuel for very special reactors built for experimental purposes, and we expect to use more for the production of power where the advantage of this highly concentrated fuel outweighs its very great cost. Natural uranium is unsuitable for any of these purposes.

The Hanford plant in the State of Washington is again unique and unprecedented. It consists of nuclear reactors using uranium metal with its natural mixture of uranium 235 and uranium 238. Fission occurs in the uranium 235, and the neutrons from that fission produce plutonium in the uranium 238. The plutonium is then separated from the surrounding mixture by chemical processing. The energy released by the primary fission of uranium 235 is unfortunately wasted at present. In fact, one of our greatest problems in the Hanford plant is to get enough of the Columbia River flowing through the reactors to take away the heat that is generated by the fission process. Like the product uranium 235 from the Oak Ridge plant, the plutonium coming from the Hanford plant is fabricated into weapon parts.

Obviously what we are actually doing is a long way from the ideal breeder reactor which is to convert the energy stored in both uranium 235 and uranium 238 into useful power. All we are doing is to extract the uranium 235 or to use some of it to make plutonium. Why aren't we making power? Why do we even throw away byproduct power at Hanford?

Fundamentally, the difficulty lies in the fact that the chain reaction does not occur as readily as was implied in my simple explanation of it. The neutrons that come out when a fission occurs in the uranium 235 atom are not very numerous and can find lots of things to do besides producing other fission in a neighboring uranium 235 atom. This means that the reactor has to be very skillfully designed and that the materials that can be used in it are extremely limited both in quantity and quality. Otherwise it will not run at all. For example, it is difficult to get energy out of the Hanford reactors because they have to be run at a relatively low temperature. They have to be run at a relatively low temperature because aluminum tubes have to be used in the reactor, and aluminum corrodes too badly if the temperature is high. Aluminum has to be used in the reactors because the less corrosive materials that are available absorb neutrons. Materials that absorb neutrons cannot be used because they prevent a chain reaction from maintaining itself.

TECHNICAL AND ECONOMIC DIFFICULTIES IN POWER PRODUCTION

The first problem to be solved in making efficient use of the energy developed by a nuclear chain reactor is to build one which will operate at high temperatures. There are a number of experimental reactors that have been designed in which this problem is solved and some of them are running. At present, they all make use of enriched fuel, that is, of uranium that has more than the normal concentration of uranium 235 in it. Most of them also use novel and expensive materials either as coolants or as structural elements of the reactors. The enrichment of the fuel and the use of expensive materials greatly increase both the capital and operating costs of these reactors. For special purposes, such as the propulsion of a submarine, this is already worth while. We have every hope that further development will bring costs down to the point where uranium is competitive with other sources of power for ordinary use.

There are two obvious ways in which costs may be brought down. One of them is to build a reactor using natural uranium fuel and producing power at a relatively high cost but at the same time producing plutonium. In other words, we need to build a reactor similar to those at Hanford except that the design and materials would be so changed that they could be run at a higher temperature and power could be produced reasonably economically. The difference between the cost of the power so produced and the power produced by a conventional coal-fired steam plant would be more than made up by the value of plutonium produced as a byproduct. Obviously the crucial question for such a plant as this is the question of how much plutonium does the Government require for military purposes and how long is it going to continue to buy plutonium?

The second avenue toward atomic power on an economic basis is the so-called power breeder. I have already described the breeding process. Ideally, a power breeder would start with natural uranium as a fuel. As the uranium 235 split up in a chain reaction, it would furnish heat but it would also produce plutonium in the surrounding uranium 238. This plutonium would in turn undergo fission, producing more energy and more neutrons which would again produce more plutonium in the uranium 238, and so on. Ideally, this process would continue until all the uranium originally present had been consumed, either in the form of uranium 235 or plutonium. In actual practice, the reaction would be stopped before the fuel was consumed because the products of fission act as impurities

to absorb neutrons and prevent propagation of a chain reaction. If this point is approached, the fuel could be extracted, processed chemically for the removal of the fission-produced impurities, and then put back into the reactor. Probably the most important factor in the cost of operation of such a power plant would be the frequency and cost of this chemical processing.

INDUSTRIAL PARTICIPATION

About a year and a half ago, the technical people inside and outside the Commission felt that developments had come to the point where a serious study should be made of the possible feasibility of building nuclear power stations on an economically competitive basis. The Commission arranged with four groups of companies to carry out such studies. It is very encouraging that each of these four groups has now submitted preliminary reports and each of them is greatly interested in pursuing the subject further. Their points of view differ considerably; some of them feel that they are nearly ready to build plants in areas where power is now costly; others are looking toward the more distant future but feel convinced that they can make radical steps in the technology which will eventually bring a real reduction in cost.

LEGAL AND SOCIOLOGICAL QUESTIONS

The interest of private industry in the possibility of building power plants using uranium as fuel has brought the Atomic Energy Commission face to face with a whole series of questions of a political and sociological nature. One reason why I described the technical background of the production of both weapons and power was to show you how inextricably mixed the two processes are. At present most of our effort is devoted to producing atomic explosives—that is, uranium 235 and plutonium. As I have explained, production of power either starts with normal uranium, in which case plutonium is an inevitable byproduct, or starts with uranium 235, in which case the initial fuel is identical with one of our atomic explosives and, therefore, predicates the manufacture of such explosive. *We cannot split the atomic energy industry in two parts, labeling one for military purposes and keeping it under Government control, and labeling the other for civilian purposes and releasing it to private industry.*

The difficulty of separating military and civilian development in the field of atomic energy was recognized when the Congress drew up the McMahon Act under which we operate. The fundamental thesis on which this act is based is that the development of atomic energy was to be under a Government monopoly. This view had the unanimous support of both political parties when the Atomic Energy Act was drawn up.

Although the law clearly establishes a Government monopoly in terms of ownership and control, it permits the use of private industry for actual operation. As you know, the Atomic Energy Commission has taken full advantage of this idea. The vast laboratories and plants which we have built or are building represent capital investment of the taxpayers' money of nearly $10 billion. But only one small laboratory is directly operated by the Government. The reasons for this method of operation are twofold. The first was to get flexibility and efficiency of management and to get it in a hurry. It would have been quite impossible to recruit a staff of some 80,000 people, many of them holding technical jobs, and to have welded them into a smooth operating force in time to be effective in meeting the needs of our weapons program. Under our present system, we make use of the existing personnel and organizations of various companies having appropriate experience. The second reason for operation by contract is anticipation of the growth of a civilian atomic-power industry. By bringing various large technical companies into the program, we diffuse the knowledge of our new techniques widely among the people who must eventually carry them on.

The reasons for Government monopoly in this field are: The need for secrecy; the need for safeguards in the matter of health; and the absolute necessity for making sure that no atomic explosives escape from Government control.

All these reasons for monopoly still exist, although certainly in the matter of secrecy and health they are less acute than when the bill was drawn. Yet there are many compelling arguments in favor of getting at least civilian power development into the normal channels of competitive private enterprise. However, many questions of law and policy must be widely discussed and solved before this can occur. To illustrate, let me make a radical assumption. Let

me assume that at some time in the future the only function of the Atomic Energy Commission would be one of inspection and regulation. Private companies would then be at liberty to buy uranium ore wherever they wanted to and on whatever price basis they could arrange. They would then build and operate their own plants for the various processes needed and would sell power to the public and would pocket the profits, if any. Were it still necessary to add to the stockpile of atomic weapons, the Government would buy the uranium 235 or plutonium from the producing companies. Let us examine what questions would have to be settled to reach this sort of situation and what controls would still have to be retained by the Government.

What would happen to the present plants which have been built by use of the taxpayers' money? Would they be sold to the highest bidder? Would they be rented, or would they be abandoned in favor of new plants financed privately? Whatever disposal is made of them, how would the rights of the taxpayer be protected? Remember that the people have paid not only for our plants, but also for the vast amounts of research and development that make the plants operable.

Several companies have had more than 5 years' experience already in operating atomic energy plants. If they were to go into the atomic energy business as private companies trying to earn dividends, what payment, if any, should they make to the Government in return for the knowledge and experience they have acquired in their period as operating contractors?

More specifically, what about patents? Assuming the transition from public to private ownership were gradual, at what point do new ideas cease to be the property of the people of the United States who paid for the initial part of the development period and then become the property of the private companies who paid for only a part of the chain of events leading to a discovery or an invention?

What about security? Unless all danger of war has disappeared, there will remain the need of keeping new ideas and developments, and any atomic explosives from reaching our enemies.

One question which seems to me relatively easy to answer is the question of health and safety. There are many processes in the atomic energy industry that are potentially very dangerous. While it is true that the Commission has made great efforts to meet these dangers and has been on the whole markedly successful, I feel that they are sufficiently like other industrial hazards to make it possible to control them by extensions of already existing State or Federal laws. It might even be possible that control in these areas could be transferred from the Atomic Energy Commission to appropriate Public Health agencies.

Assuming that the Government still needed atomic explosives, how would the price of uranium 235 and plutonium be set? And, how is the Government to be assured that it would get as much atomic explosive as it desired? Would there be some transition period when a plant producing both power and plutonium would in effect be subsidized by setting the price of the plutonium high enough to make the price of power competitive with that from other sources?

How would the Government assure itself that it knows exactly where all raw materials and all fissionable materials are so that there is no chance of their diversion to our enemies?

Finally, who would pay for the continuing research that is necessary to improve processes for civilian and military purposes? One of the reasons for the present Government monopoly is recognition of the fact that we know very little about the scientific laws governing the fundamental process of nuclear fission and also know very little about the new technology on which the successful use of the fundamental phenomena would be dependent. The Commission spends somewhere between $100 and $200 million a year on research and development. It is very easy to justify this expenditure at present both in general terms of the kind of knowledge we need but do not have and in specific terms of improvements which have come out of our research program. It is questionable whether private industry could support research at this level. On the other hand, public money should not be used to support research if the results of that research would benefit only a specific section of private industry. Possibly the solution would lie in the continued support by the Government of what we ordinarily call basic scientific research and in the elimination of Government support of development work.

None of these difficulties appear to me to be inherently insuperable. They could, of course, be avoided by maintaining the Government monopoly and putting the Government still more into the power business. The only difference between

our present operation and such an operation would be that we would sell power to the public as advantageously as we could. Much as I would like to see the Atomic Energy Commission converted from a spender to an earner, I recognize many objections to this possibility.

FUTURE NEED FOR URANIUM ORE

You are all connected with the mining business. Some of you are specifically interested in mining uranium or thorium. You would like to know what the probability is for the demand for this material. Will it continue at a high level? What I have tried to do in this talk is to give you some basis for making your own guess about this question, because I think any answer to this question at the present time is a guess. Evidently, if world conditions continue unsettled, there will be a continuing demand for uranium for military purposes. Even if we should reach a point where our stockpile of atomic weapons is so huge that any further addition to it is unnecessary, we might still have some demand for uranium for special power purposes connected with military preparations for defense. It is difficult to estimate how great this would be.

The estimate of possible demand for uranium for civilian power is also a guess depending as it does on unsolved technical and economic problems, to say nothing of the sociological and political problems which I have been reviewing. It is my own belief that the use of uranium for power purposes will become economically feasible before the need of uranium for military purposes begins to slack off. Therefore, I believe there is going to be a continuing demand for uranium ore.

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4. INDUSTRY'S NEXT STEP IN ATOMIC ENERGY

By T. Keith Glennan, president of Case Institute of Technology, Cleveland, Ohio; former member United States Atomic Energy Commission; for delivery at the semiannual meeting of the Manufacturing Chemists' Association, Inc., New York City, November 25, 1952

It is a genuine pleasure for me to be here tonight, among so many old friends, and to talk to you about atomic energy.

This occasion will always be a memorable one for me, for it marks my first public appearance as an ex-United States Atomic Energy Commissioner.

It is perhaps because of my connection with the academic world that I am inclined to look upon this event as a kind of commencement exercise, and this address as my valedictory insofar as my service on the Atomic Energy Commission is concerned.

In any case, I believe it presents an unusually appropriate opportunity for me to look backward at some of the lessons I have learned during my 2-year course in atomic energy administration—and looking forward—to suggest some of the ways in which these lessons might be applied by industry to advance the cause of peaceful atomic energy development. Before I finish tonight I hope to have developed one such suggestion in brief outline form.

I came to the Atomic Energy Commission in October 1950, and I shall be the first to admit that I did not bring with me any great familiarity with the nature of the program or the scientific principles upon which it is based. Atomic energy was new to me, and I was, frankly, in the position of the old dog who had to learn some new tricks.

I did not, however, come empty-handed.

Among the things I brought with me—in addition, of course, to my desire to do what I could for the national defense effort—was a strong belief in the essential rightness of the American system of free competitive enterprise, and a strong conviction that it could be made to work in the development of atomic energy just as effectively as it has worked in all the other industries which have helped to make the Untied States the great free nation it is today.

I brought also an awareness of the apparent anomaly in the atomic energy law of this country, which on the one hand says that atomic energy should be used to strengthen free competition in private enterprise, and on the other grants to the Government a 100-percent monopoly.

I brought also an ingrained suspicion of the motives, subconscious or otherwise, of a Government agency that possesses the powers and prerogatives enjoyed by the Atomic Energy Commission—particularly when these powers are derived

from the right to own and manage—in nearly complete secrecy—a very large and promising new industry.

And I brought a strong desire to do what I could, while I served on the Commission, to make room for and to encourage the legitimate participation of industry in the national atomic energy program in something other than the role of a contractor performing an assigned task.

It would of course be very neat and effective to say that "I came, I saw, and I conquered." But this would not only be glib, it would also be untrue and grossly unfair to the Commission.

What actually happened was the education of Keith Glennan. I like to think that this was not entirely unilateral, but whether it was or not, I do know that I learned a great deal, and that I have had an immensely valuable and stimulating experience that I wish all of you could have shared.

When I arrived at the Commission in the fall of 1950, I found—not a group of bureaucratic ogres secretly plotting the erection of a permanent socialistic empire—but rather a group of able, sincere, earnest, patriotic, and hard-working men doing a job.

Evidence of the kind of job they are doing, and of the sense of urgency with which they approach it, can readily be seen in the weapons tests at Nevada and Eniwetok; in the new plants going up in Tennessee, Washington State, Kentucky, South Carolina, and Ohio; and in the prototype power plant for a submarine in Idaho.

The Commission's job today is a research and development job, a construction job, and a production job. It is the kind of a job that involves running a billion-dollar-a-year operating industry, while, at the same time, trying to increase the capital investment of this industry more than $6 billion in the space of the next few years. It is the kind of a job that one cannot do without tending strictly to business, and it doesn't leave very much time for philosophizing about the future.

But it would be entirely wrong to assume that the Commission has been so preoccupied with the problems of the moment that it has given no thought to the larger questions of the future. Actually, even in the midst of the hullabaloo of the construction and production programs, the Commissioners have found time to devote a good deal of attention to the future, and to such questions as the ultimate role of competitive enterprise in the atomic industry.

I am pleased to say that I had not been on the Commission very long before it became apparent to me that the views of the other Commissioners on this fundamental question of industrial participation were not basically different from my own. Naturally there were differences on such details as timing, methods, and so on, but essentially, I would say, there was agreement on the principle that free enterprise should absorb as much of the atomic energy industry as it is able and willing to absorb without damage to the national security or to the real public interest.

As evidence of this, I would point to the Commission's decision of about a year and a half ago which permitted eight private concerns, divided into four groups, to come into the program to study the feasibility of producing atomic power in privately owned—and, to some extent, at least—privately financed plants. Incidentally—several additional companies are beginning to make similar studies this year.

The Commission had two possible decisions it could have made when it was approached by these groups: It could have said, "Go away, you bother me," or it could have said, "Come in and look around." It chose to say, "Come in and look around."

I sometimes think that the full significance of this important episode in the development of atomic energy has been missed. To my way of thinking, it produced two valuable lessons which industry would do very well to heed:

First, it demonstrated that the Commission's attitude toward private participation is basically sympathetic; and

Second, it showed that—in this case, at least—progress was made on industry's initiative, not the Government's.

Actually, if you will think about it for a moment, I believe you will see why the Government cannot be expected to carry the ball alone on this matter of industrial participation. The Commission's main job, as described in the atomic energy law and as dictated by the times, is to guarantee the common defense and security. It is a big job, and a time-consuming one, and if anyone thinks that the Commission can take time off from its defense work to look around for something to hand to industry on a solid plutonium platter, he is not being very realistic.

Let there be no mistake about it: Industry will get only those things that it can prove it really wants, it really can handle, and it really should have in the public interest.

As many of you doubtless know, this a theme which I have followed with some variations in nearly every public appearance I made as a Commissioner. In essence, the message I have tried to get across is this: Industry must get into this atomic energy business with its own money and at its own risk, and, to do so, it must be willing to take some real chances, and it must knock persistently on the Government's door with ideas, suggestions, and concrete, well-thought-out proposals, and—most of all—questions. It is the questions that have been talent which it is supposed to possess in such great abundance: initiative.

Now that I am in a position to look back at my earlier public statements with the perspective that time and experience bring, I must confess that there were some elements of naiveté in my approach. In effect, I invited industry to beat a path to the Commission's door. Industry did. The path is not as wide nor as well-trodden as I had hoped it would be, but it is there and being used just the same. Industry has come to the Commission's door bearing ideas, suggestions, proposals, and—most of all—questions. It is the questions that have been by far the most provocative and challenging contribution, and they have added up to significance that I had originally not fully appreciated.

At first the questions were not too difficult to handle. Briefly, they went something like this:

What is the state of reactor development?

What does it cost to build a reactor?

What information do you have on new materials?

These questions were not too difficult to handle because most of them were technical questions, and they could be answered under the present law and under the Commission's present administrative policies by permitting cleared representatives from industry to come into the program and see for themselves what was going on. This was what we might call the "study phase," where the Government was not required to give up any of its rights, and industry was not required to put up any money beyond that which was necessary to carry out its investigations.

But now the questions are getting harder, and I am afraid that, whereas my earlier exuberance may have helped to raise them, I know it has not been of much help in providing the answers. It is now obvious, I think, that it takes more than a knock on the Commission's door to get industrial participation off the ground; it takes a serious joint Industry-Government effort to resolve fairly and realistically the many problems with which both are faced.

To give you an idea of what these problems are, let me mention just a few of the many questions industry is asking today. They go something like this:

If we put up some of our own money, what rights can we expect in return?

Can we own atomic energy facilities?

Can we locate these facilities wherever economic factors dictate or will there be other considerations?

Can we own patents on things we develop at our own expense?

Will we have access to the nuclear fuel we will need if we build a reactor for power?

If we produce plutonium, will the Government buy it from us for military use; and if so, what will the price be and for how long will it be guaranteed?

As you can see, the character of the questions being asked by industry has changed a good deal in the last year or two. Instead of technical questions, they are now primarily questions which any prudent investor might ask. Before they can be answered with any degree of realism or assurance, the Government must take a position on some rather fundamental policy issues.

For example, the Government must decide how far it can go along with industry without inhibiting its ability to protect the national security and the public's legitimate interest in such matters as health and safety and its own very large investment in the atomic energy program. As practical matters, the Government must decide what it is going to do about such things as patents, materials allocations, private ownership, subsidies, and secrecy, and it must decide whether now is the time to change the atomic energy law, and, if so, how it should be changed.

Now, who is to settle these issues? Are they to be settled by a group of Government experts meeting in secret, or are they to be settled in the traditional

American way—out in the open, in a national forum where the views and interests of all sides can be fairly represented? Are the answers to come down from Olympus, or up from the market place where the people most affected conduct their business? It is worth remembering at this point that the present atomic energy act was debated publicly for many months before it was enacted.

Admittedly, the need for answers to these many questions is urgent. But I do not believe that the urgency is so great that the answers should be arrived at by fiat. Answers of this sort, I feel, would not only be unrealistic, they would also tend to be weighted on the side of those who have had a long-standing interest in the course of atomic energy development, and who possess, as of the present, the machinery for bringing their points of view to the attention of the Atomic Energy Commission.

This is not a criticism of the Commission; it is simply a recognition of the fact that the Commission must make its decisions on the basis of the information it has before it. And if it does not have all the information and advice it needs, it cannot very well make the wisest possible decisions. And, I might add, neither can the Congress.

So let us look for a moment at those who have a real and obvious interest in the course of atomic-energy development, and at the machinery through which these interests are represented.

First and foremost, of course, there is the Department of Defense. The military services rely upon the products of the atomic-energy program to a very large extent in discharging their responsibility to protect the national security, and they have a need—not only for bombs and other kinds of atomic weapons—but also for atomic reactors for the propulsion of submarines, aircraft, and surface vessels. As guardian of the national security, therefore, the Department of Defense obviously has a real and legitimate interest in the Atomic Energy Commission's work.

Look for a moment at the machinery through which this interest manifests itself. To say that it is ample would be an understatement. Not only does the Department of Defense have direct access to the President, from whom the Atomic Energy Commission takes its orders, it also has a very close working relationship with the Commission itself. For one thing, there is a Military Liaison Committee provided for by law, its chairman appointed by the President and its members appointed by the military services. This committee meets regularly with the Commission; it maintains offices in the Commission's own headquarters, and it employs a staff of more than 50 people to make sure that the military position is represented constantly before the Commission. Its members also make frequent appearances before the Congress.

Behind the Military Liaison Committee there are hundreds of other people in the Armed Forces special weapons project and in the military services who devote their time exclusively to atomic energy. They have access to the secrets pertinent to their work, and they have a detailed knowledge of the Commission's program and how it does business. They are both in Washington and out in the field, and they turn up on scores of joint working committees.

I'm not saying that all of this is bad. Most of it is clearly necessary. All I'm saying is that it exists and that it more than adequately provides the machinery by which the military point of view can be represented in the field of atomic energy.

The second great body having an interest in the work of the Commission is the general public. The public has put up the money—$12 billion of it—that the atomic-energy program has received, and the public also has a clear interest in the products of the program: In the weapons that today protect its security and in the good things that tomorrow will enhance its welfare and standard of living.

But how is the public interest protected? Again I would say that the machinery is at least adequate. When the Atomic Energy Commission was established, there was also established a Joint Congressional Committee on Atomic Energy whose sole purpose is to "watchdog" the Commission on behalf of the taxpayer and the general public. This 18-member committee has access to all the secrets; it receives voluminous reports on all the Commission's activities; it holds frequent hearings, both off and on the record, and it maintains a staff of about 20 people to probe through the entire Commission operation.

Add to the work of this committee the studies, investigations and hearings of the House and Senate Appropriations Committees and such other groups as the Small Business and Educaiton and Labor Committees of Congress, and I believe you will begin to see that machinery exists for the protection of the public interest in atomic energy.

And who else has an interest? I would say that the scientists do. After all, it is upon their brilliant research that the whole program is based. Since the Commission itself conducts scientific research and supports it elsewhere, scientists also have a direct interest in the day-to-day work of the Commission. They have an interest, and they have the machinery through which this interest can be demonstrated. This machinery is the General Advisory Committee, a statutory committee of elder statesmen from the fields of science and engineering appointed by the President to make recommendations to the Commission on the course of scientific development. This committee has access to the secrets, it meets regularly with the Commission, and it maintains a small liaison office within the Commission's headquarters.

I think it is clear, then, that the military, the general public, and the scientists all have a direct interest in the atomic-energy program and that they possess the means through which this interest can be fairly represented.

But are these the only groups that have a major interest in the course of atomic-energy development? I think it is obvious that they are not. Industry built the atomic-energy program; industry carries on nearly all of the work today under Government contract, and industry stands ready to utilize the peaceful results of atomic research in its own operations and for the benefit of society. I think it is entirely fair to say that no one has a greater interest in atomic energy than industry. It might also be said that, because of secrecy restrictions and compartmentalization, no one has an interest that is less clearly defined than that of industry.

Now let's look at how this industrial interest is articulated. For the first time we encounter a void. There is no liaison committee, no statutory advisory committee, and no machinery through which the interest of industry as a group can be brought to the attention of the Commission. It is not a complete void, of course, There have been temporary advisory committees, named by the Commission itself, and serving at the pleasure of the Commission and under terms of reference provided by the Commission. There is also a very close working relationship between the Commission and its individual contractors. But the voices the Commission hears from industry are individual voices, many times divided, and many times raised in ignorance of the latest developments and of the Commission's total range of activity. They are not the kind of voices that can have much of an impact because they are not the kind of voices that speak from an informed point of view.

I think I am reporting accurately when I say that recently the Commission has become increasingly aware of the fact that there is no single, unified, representative and continuous voice from industry to balance the other voices which are beamed so consistently in its ear. This state of affairs need not continue. But the corrective measures should come—not from governmental urging—but rather as a result of industries own initiative.

In the short time that has passed since I left the Commission, I have given a good deal of thought to this question of how industry might contribute to its own understanding of the potentials in this field and provide, as well, informed counsel to the Commission and to the public. I have thought about it, and I have discussed it with a number of people in both industry and Government whose opinions I have come to respect. Out of this activity there has been distilled a suggested program which I'd like to lay before this audience tonight.

Briefly, my proposal is this: That those industrial concerns, institutions, and individuals, that are today actively engaged in atomic energy research, development, and operations, form—voluntarily and without governmental urging or subsidy—a national association of atomic industries.

I would propose that this association be established in the District of Columbia and that it develop a close working relationship with the Atomic Energy Commission, the Joint Congressional Committee on Atomic Energy, and other appropriate agencies of the Government.

I would propose that the broad aim and purpose of the association be to foster and encourage—subject, of course, to the requirements of national security—the development and utilization of the peaceful applications of atomic energy in accordance with the best traditions of the American system of free competitive enterprise.

And I would propose that the association seek official recognition to the extent that those of its officers and staff who have not already been investigated and cleared for access to information required in the peaceful development of atomic energy, be so investigated and cleared.

To me, it is quite obvious that such an association could serve, among others, the following useful purposes:

(1) It could provide a forum in which the atomic-energy industry could arrive at an informed and perhaps a common position on such matters of vital concern to it as the ownership of atomic-energy facilities, rights to patents, licensing regulations, health, and safety standards, secrecy policies, personnel-clearance policies, and contract and tax procedures;

(2) It could provide a channel through which industry's position on these matters could be brought to the attention of the Atomic Energy Commission, the Congress, and the public at large; and

(3) It could provide a mechanism for the acquisition and dissemination throughout industry generally of information on such matters as laws and regulations, business opportunities, and new technological developments.

In other words, such an association could serve as the national forum, the national spokesman, and the national information clearinghouse of the atomic-energy industry.

I realize fully that there are a great many problems involved in the establishment of any new association, society, or institute such as this. I can see, for example, how the problem of membership is made more difficult by the fact that atomic energy is today controlled, and, to a large extent, owned by the Government. Membership would have to be set up on such a basis as to avoid the appearance or the reality of its becoming a "closed shop" type of association where only those on the inside might belong. I can see, too, how the problem of operating an association in the atomic-energy field would be complicated by the fact that a large amount of the information with which it would deal is today marked "Secret." And here one would wish that provision might be made for those not now active in the field to gain information, but on a basis such that security would be maintained.

But I do not believe that these obstacles are insurmountable. In fact, I believe the advantages of such an association are so great and so obvious that the time and effort it would take to find solutions to the problems involved is a small investment indeed compared to the many benefits that would accrue to industry and to this country.

No matter how such an association would be set up—assuming one is set up—I would hope that the following types of industrial concerns, institutions, and individuals would have an opportunity to participate in it and to have a voice in the management of its affairs:

(1) Those engaged in the production of atomic-energy source materials, such as uranium and thorium;

(2) Those engaged in the production of fissionable materials;

(3) Those engaged in the utilization of fissionable materials for such purposes as power production and weapons manufacture;

(4) Those engaged in the production, distribution or large-scale utilization for industrial purposes of such products of atomic energy as radioisotopes;

(5) Those engaged in the design or construction of facilities uniquely applicable to atomic-energy use, such as nuclear reactors and chemical-processing facilities;

(6) Those engaged in the manufacture of materials and equipment primarily useful in atomic-energy work, such as beryllium, zirconium, radiation-detection instruments, and particle accelerators;

(7) Those engaged, with either public funds or their own private funds, in studies and in research and development projects related directly to the industrial application of atomic energy; and

(8) Those other individuals in industry who, for one reason or another, are cleared for access to secret information.

In other words, if such an association were to be established, I would hope that all those with a real stake and a real interest in the industrial future of atomic energy might be permitted to participate in an active and responsible way.

I would hope also, that the nonsecret informational benefits that would accrue from membership would never be denied to those who are not today actively engaged in atomic-energy work. Since one of the principal purposes of such an association would obviously be to broaden the industrial base of atomic energy, it would be less than intelligent, in my view, to restrict these informational benefits to those who are already in the tent.

I can see, therefore, where it would be highly desirable to include in the association a class of membership which would not necessarily carry with it all the privileges of regular membership, but which would permit full participation in all nonsecret symposia, meetings, discussions, and informational services. Such a class of membership would, in my opinion, be extremely useful to those companies, institutions, and individuals who today have no place in the atomic-energy picture, but who are sincerely interested in becoming acquainted with it in the hope of future participation.

In the main, such an association could and should provide a forum in which industry might develop its best thinking in the interest of the advancement of the peacetime uses of atomic energy; a forum in which industry might develop an informed voice to be heard at governmental levels as new atomic-energy policy is hammered out; a forum, not to serve the narrow interests of a few, but to stimulate the industrial development of atomic energy for the good of all.

And that is not all that I would hope such an association would accomplish. I would hope also that it would make a real effort to help industry to recognize and understand its own very heavy responsibilities in the atomic field, so that it might prepare itself to assume them—not only in its own interest, but in the public interest as well.

To my mind, there is no question but that the enlightened self-interest of competitive enterprise in the course of atomic-energy development is also the public interest, and I don't think I am alone in this belief. For evidence of this, I need only point to the atomic-energy law of this country, which declares that one of the principal objectives of the atomic-energy program is the stimulation of free competition in private enterprise.

I know there are those who may suggest that many of the same objectives of an association of this nature could be achieved just as well if the Atomic Energy Commission would only appoint a permanent industrial advisory committee. With this I cannot agree. And in saying this I am mindful of the thoughtful efforts of Jim Parker's advisory committee 3 years ago and of Phil Sporn's committee more recently. Not only would such an advisory body be poorly equipped to perform the same kind of information job for industry, it would also, I strongly believe, find itself rather severely inhibited in its efforts to represent industry's point of view to the Commission and to the public. In essence, such a committee would be a captive, or "kept" committee, selected by the Commission and serving at its pleasure. Under these conditions, it would be very difficult, at best, for it to hold permanently the confidence of either industry or Government.

What is needed here, instead, is something that comes up from industry, not down from the Government—something that is based upon and can effectively demonstrate the serious interest and enthusiasm that industry has in and for atomic energy. This is the sort of job that can be done for industry only by industry itself.

I have heard a great deal during recent months about what industry thinks Government should do in atomic energy. Industry, however, has people with ideas, people with technical skills, people with legal knowledge, people with executive ability, people who can be articulate, and people with brains. It is high time that industry began to put some of these people to work—and to begin to do for itself what it has too long been asking the Government to do.

Let me emphasize one thing—there is a vacuum building up in atomic-energy policy. It is a vacuum that is being created by the technological advancements that current policy will no longer fit. This technical progress is leaving a vacuum that is going to be filled one way or another, and if it is not filled by industry, on its own initiative, it is going to be filled in some other way.

In my opinion, the next session of Congress will find itself debating changes in the Atomic Energy Act. Security standards, matters relating to patents and ownership of facilities now prohibited under the law are probable subjects for such debate. The entire development of this field to date of necessity has been Government-controlled and publicly financed and it is necessary, in presenting a case for industrial participation on a broader scale, that industry recognize that the tremendous volume of information now held in this field has been acquired almost wholly at public expense. The Commission must keep this fact constantly in mind and must develop a policy that protects the public interest. It is not a foregone conclusion, however, that this important consideration makes necessary the further development of the field by a Government agency.

I have been out of the Government for such a short time that I still find it hard to get used to the idea that I am once again a private citizen. But as a private citizen, newly returned to the free competitive enterprise fold, let me address, in closing, this one final message to the atomic-energy industry:

"In this thing we have that is called atomic energy, there is untold promise for the future—in power, in propulsion, and in the utilization of nuclear radiation in a thousand ways not yet even dreamed of.

"Let's make our play, put in some chips and hasten the realization of some of this promise. Let's bring atomic energy out into the main stream of the economic life of America. Let's bring it out where the initiative and varied talents of the competitive-enterprise system can be brought to bear upon the problems of atomic-energy development—for the good of industry, for the good of the country, and for the good of mankind."

APPENDIX C

The following are seven speeches and articles by Dr. Lawrence F. Hafstad, Director of the Atomic Energy Commission Reactor Development Division.

1. ATOMIC POWER AND ITS IMPLICATIONS FOR AIRCRAFT PROPULSION

Remarks Before the Institute of Aeronautical Sciences, Los Angeles, Calif., July 22, 1949

It is indeed a privilege to meet with this particular group tonight to present my impressions of the problems involved in the development of nuclear reactors, first in the general sense, and second, for the specific purpose of use in aircraft.

This group is especially qualified to appreciate the nature of the problems involved, both from a technical and from a policy point of view. Reactor projects have much in common with aircraft development projects. Both are expensive and risky. In both fields, one must obey the precept "Be bold, be bold and ever more be bold, but be not too bold." Following that advice takes more than technical knowledge. It requires wisdom.

This report tonight is timely, too, for since I have been with the Commission just long enough to learn the ropes, I should be able to give you the impressions of an outsider who has had the privilege of getting a good, hard inside look at the Commission's reactor program.

Of course, this assumes that I will be skillful enough to handle the security questions involved. Fortunately, I do not think this will be too difficult. What our competitor wants to know is, "What solutions or promising approaches have we found to specific technical problems?" What you gentlemen are probably most interested in is: "Is the objective we have set for ourselves worth attaining and are we going about it the right way?" These are questions peculiar to our own situation and our own frame of reference. The answers we get are certainly not those which are applicable to our competitor. In this area, therefore, we can afford to be frank without giving aid and comfort to the competitor.

Let us see if we can get squarely in mind just what are we trying to do in the over-all atomic-energy effort? Not with respect to specific technical projects, but what are the things we have to do in a broad sense? These are, I would say:

First: To maintain undisputed leadership in technical knowledge and facilities for the United States in all areas of the atomic energy field, either for war or peace.

Second: To establish a trained corps of personnel familiar with all areas of atomic research and in particular with nuclear radiation and its hazards. This corps is our standing army of the modern age, and would have to be maintained to serve in time of war, even if not organized to contribute in time of peace.

Third: We want organized task forces sufficiently competent to explore, and sufficiently alert to exploit any technical advance, which has promise for either peace or war.

Fourth: We want the wisdom to see that the effort expended in the above activities is somehow kept proportional to the probable returns.

As part of the above, some kind of a reactor program is an essential part of the over-all effort. Reactors are the machines for giving us the controlled release of nuclear energy, and as such, certainly have promise both for peace and for war. Though the spectacular aspects of nuclear energy has been oversold in the popular press, the stubborn fact remains that one pound of uranium can be persuaded to release an amount of energy equivalent to 2,000,000 pounds of coal. When all is said and done, atomic energy is certainly not the magic perpetual motion machine which has been publicized, but it has the inherent possibilities of providing an incredibly compact storage battery.

Let's look at this analogy a little closer. Our ordinary automobile battery delivers 6 volts and has a capacity of about 100 ampere-hours, or a total power storage therefore of very roughly, one horsepower-hour. A weight of uranium equal to that of an automobile battery would be capable of delivering about 300,000,000 horsepower-hours. Edison was a great inventor, but the famous Edison cell, produced after years of effort, brought forth an improvement of only 30 percent over the conventional lead cell compared to a conceivable 300,000,000 percent for the uranium energy source. I will return to the many difficulties later, but this analogy shows the challenge of the problem, the conceivable rewards, the pie in the sky. It would seem that the possibility of nuclear reactors for power production must at least be explored. The forty-niners had much less incentive.

What else can reactors be used for? In addition to energy, reactors produce neutrons. These in turn can be used to produce radioactive isotopes, or to produce more, or other, fissionable material. So long as concentrated energy sources are desirable, fissionable material will be an economic good. A stockpile of fissionable material would certainly be more useful than the gold at Fort Knox. In war, it could be used for bombs and might be used for propulsive power. In peace, it would be available for civilian power insofar as the supply and the economics of the situation would permit. It would appear, therefore, that a stockpile of fissionable material is indeed desirable. Accepting this, then considerable effort would appear to be justified on a special type of reactor called a breeder, which shows promise of helping to maintain, if not even augmenting, our supply of fissionable material.

To describe a breeder we must digress for just a moment to a technical detail. As most of you know, the element uranium, as it occurs in nature, is composed of two kinds, one variety slightly heavier than the other. The fissionable variety from which we can get energy has a mass of 235 units. The other, unfissionable, has a mass of 238 units. The U–238 form is 139 times as prevalent as the U–235 form. The trick in a breeder type of reactor is this: With a proper choice and arrangement of materials, the neutrons which are produced in the initial natural U–235 fission processes can be captured—*after* they have released their energy—by the atoms of unfissionable U–238 and as a *byproduct* used to convert the U–238 into a fissionable form of material. Thus it is conceivable, not only that energy can be extracted from U–235, but that as a byproduct we acquire a potential stockpile of fissionable material 139 times as great as we had when we started. With such a stockpile we might have a chance for diversions to power for civilian uses. Again we have a challenging goal and unless we have lost our zest for adventure, it is a goal from which we will be deterred only by a convincing demonstration of its scientific impossibility.

If reactors are so desirable, why don't we go ahead and build some? Now we come to the difficulties. Here are a few of them:

1. That for any reasonable thermodynamic efficiency in utilizing the great energies available, it is necessary to operate at temperatures well above the conventional engineering range.

2. The compactness of reactors, which is an important inherent advantage, proves troublesome in regard to the heat transfer problems which involve heat transfer rates far transcending previous experience.

3. The materials chosen for the reactor must withstand not only high temperatures but also high nuclear radiation densities, with unpredictable changes in the physical properties of the materials concerned. The seriousness of this problem can perhaps be visualized by this kind of a comparison. How would you like, for example, to design airplanes or engines if, in use, the properties of the aluminum and steel would gradually change to those of cast iron or lead?

4. If we finally find a structural material for reactors which appears suitable so far as physical properties are concerned, we must now add still another requirement. The nuclear properties must be such that the structural material will not capture neutrons and thus deplete the supply and reduce the power. This requirement drives us to consider strange new elements, and raises a whole array of procurement problems.

5. Even after we have our reactor working we find that the fission products produced as an essential part of the reaction "poison" the reaction itself. The ashes smother the fire. Now you gentlemen are well aware of the enormous maintenance problems for aircraft engines. Every 800 hours they must be disassembled, inspected, have defective parts replaced, and then reassembled and tested. The work is staggering. However, how would you like it, if instead of merely disassembling, the entire engine would have to be dissolved in nitric acid,

and the rebuilding of the engine started with getting a solution of certified chemically pure iron? This is the fuel reprocessing problem.

6. Finally, assuming we have solved the structural problems listed above, we have a whole new category of problems in connection with the working fluid or heat transfer medium used to convert the heat into power. The nature of these problems can be suggested by the fact that from rough comparisons of the volumes of reactors and the present highly perfected aircraft engines, the rates of heat transfer must be more than an order of magnitude greater for nuclear reactors than for conventional engines. Orthodox advances will not be sufficient. The problems involve the use of liquid metals with all the associated corrosion, erosion, purification, and pumping troubles which we can readily imagine as being associated with those elements which appear to have suitably low melting points.

When one considers the host of difficulties and troubles which lie in the road ahead in the development of atomic power the problem does look formidable. I am reminded of a statement made a little over a hundred years ago by the great chemist, Wöhler, in regard to the status of organic chemistry at that time. Wöhler wrote to Berzelius as follows:

"Organic chemistry just now is enough to drive one mad. It gives me the impression of a primeval tropical forest, full of the most remarkable things, a monstrous and boundless thicket, with no way of escape, into which one may well dread to enter."

That's an excellent description of the atomic-energy field righ now, in 1949. In the meantime, however, what has happened to organic chemistry? Well, newspaper headlines give the answer. Miracle drugs are practically tailor-made these days. DDT and 2–4,D are taken for granted by the farmer. Synthetic rubber threatens to displace the natural product. A hundred years from now what will be the status of atomic energy? Who now has the wisdom to predict either failure or success?

We can all hope for the era of free power and effortless living usually associated with the atomic age. This implies the successful development of large, land-based, electric-power-producing reactors. We have also heard discussed the military advantages which might be gained by nuclear propulsion of ships and aircraft. I will discuss these in more detail later but the point I want to make now is that whereas the technical problems would be least in the land-based power reactor, and progressively more difficult in the ship and aircraft reactors, the present urgencies or priorities are just the other way around. Perhaps fortunately, however, the same ground must be covered in the initial stages whether the ultimate purpose is for civilian or military use. We might take as an analogy, a transcontinental journey, starting from Washington in the frontier days. Whether the ultimate goal was Oregon or California, the route was the same through Cumberland Gap and on to St. Louis. To complete our comparison we might put civilian power in California and military power in Oregon. These are the things we dream about. At the moment we are really only approaching Hagerstown, and our worries and our plans are all concerned with surviving the hazards of the journey to St. Louis.

I don't need to stress before this group the importance of the incentive given to technical developments by military needs. This group is well aware, I might even say, painfully aware, of the vicissitudes of the development of the airplane to the highly perfected state in which we have it today. Similarly in the atomic-power field it appears that military needs will have to provide the incentive to carry through difficulties, for progress, even though ultimate dividends may be expected in the civilian economy.

Going further back into history, we can cite the difficulties of converting ships from wood to steel. Again, the incentive was military, but note this quotation:

"Early experiences with iron as the material for hull construction were far from reassuring. In England where several iron warships had been completed by 1846, firing trials conducted in 1845 and in 1850 indicated that 32-pounder and 68-pounder shot striking iron plating were likely to break up and form more splinters from the shot themselves and the iron of the target than were caused by the impact of the same shot upon wooden targets. Accordingly, the British Navy pronounced iron to be an unfit material for hull construction."

Only if both the opportunities and the difficulties in the field of atomic energy are fully appreciated can the history of the atomic developments over the last several years be understood. This is a field in which the experts disagree. The more distinguished they are the more violently do they disagree. (At this point, I want to disqualify myself as an expert. Scientists live and work

in laboratories, not in marble buildings in Washington. I am an ex-scientist now. My job is to be a good listener and an accurate interpreter.) When experts disagree, a middle-of-the-road course of action is indicated and this indeed is what we have in the Commission's reactor-development program.

As has been announced, and as presented in budget hearings before Congress, so there are no security questions involved, the Commission program consists of two main parts. The first is a strong applied research program seeking to establish the basic facts, the handbook data if you like, which will ultimately be needed in solving the reactor design problems. For the reactor program the center of this type of authority is at the great Argonne Laboratory at Chicago.

Due to the foresight of the Manhattan district and its advisers, and to the continuing generous support by the Commission and Congress, the Nation has an exceptionally well-supported predominantly nonmilitary applied research program in the atomic-energy field. In the large national laboratories we have thousands of people working on and becoming acquainted with atomic-energy problems. In our atomic-energy production plants we have thousands more. These people are our standing army, mentioned above as requirement No. 2, and our preparation for any eventuality of the so-called atomic age.

But it will take more than the accumulation of a library full of knowledge to get power-producing reactors. We have 40,000,000 automobiles on the roads of the United States but we still do not "understand" the mechanism of combustion. It is for this reason that the second part of the Commission's program is the engineering development and construction of a series of definitely experimental prototype reactors. These represent assignments to specific task forces as mentioned in requirement No. 3.

Of course, the Nation has had reactors of various kinds, from almost the beginning of its atomic energy program. The famous chain-reacting pile at Chicago was the first of such reactors. A series of reactors was built during the war culminating in the huge single-purpose production reactors at Hanford. Other reactors have since been built but these are by and large, research type of reactors, small in size, and none of them capable of producing useful power in appreciable amounts. The next phase in the historic development of reactors calls for designing and constructing of reactors which are larger, more complicated, and more difficult to build than any we have produced thus far. As in any new technical development, there are many uncertainties and many risks involved. It is here that the experts disagree on details of designs of reactors which will do the jobs that need to be done. Largely, for this reason, in the 4 years since the end of the war, no really new or greatly improved versions of reactors have been built in this country. The reactor of most advanced design and performance is in Canada.

The proposed reactor development program of the Commission crystallized out of the 4 years of discussion and argument as well as from new knowledge gained from the applied research program since the end of the war. Reactors can conceivably be used for a wide variety of purposes. Special reactors of many types have been proposed by responsible people for purposes varying from small compact units for propelling guided missiles, to huge stationary power plants for providing cheap electric power for supplying our great cities and distilling ocean water for irrigating our deserts. To the people most fully informed, it is clear that the difficulties of building any reactor are so great that only a very few projects can be adequately supported with money and particularly with competent technical manpower at the present time. It is for this reason that it is essential from the multitude of possible reactors, only a few carefully selected projects should be chosen and very strong technical support should be focused on these few.

Getting back to the fundamentals, a reactor can be made to produce two things: First, a large number of neutrons, and second, a large amount of heat or power. At Hanford, in the production reactors, the neutron supply is utilized for the conversion of the nonfissionable uranium 238 into fissionable plutonium for use in atom bombs. In the existing Oak Ridge reactor, again the neutrons are used for the production of isotopes for peacetime research purposes. In both cases, the heat generated is wasted—it is lost in water coolant at Hanford, in air coolant at Oak Ridge. At the present time, there are no reactors in existence so designed that the heat produced can be made to serve useful purposes.

An obvious forward step would be the design of a reactor in which the neutrons produce fissionable materials as in the existing production reactors, but in addition, the heat generated is put to work. Unfortunately, scientists and engineers at present do not have enough basic knowledge to design such obviously

desirable reactors. Their first step would appear to be to produce a reactor specifically for the single purpose of generating large amounts of heat at temperature which will permit conversion to power. So extensive is our ignorance, however, that even such a simplified design is forcing us into pioneering activities beyond the present boundaries of human knowledge. Before any reactor can be built with a performance appreciably better than those we now have, a large amount of applied research in very specialized fields is necessary. This is the activity with which our laboratories have been preoccupied for the last 4 years.

We are now at the stage where, if we intend to progress further, it will be necessary to find the courage to build a few reactors, to test what we think we know. The reactors in the Commission's program are essentially experimental prototypes. None of them can be described as an "end item" which will drive an airplane or a ship, or power and light a city. Further generations of reactors will be required before such desirable goals can be attained. It is this fact which sets a time scale of 10 to 20 years before useful and economical civilian applications of atomic power can be expected. However, if the ultimate goal is ever to be attained, the first steps must sooner or later be taken, and it is these first steps with which we are concerned in the present reactor program

As described by Dr. Robert F. Bacher, former Commissioner, and a moving force in reactor development work, the current program consists of four reactors:

(*a*) The first of these has been designated as a materials-testing reactor. We call it MTR. While it is itself an experimental reactor, as its name implies, it is intended also to give information on the behavior of materials in reactors so that larger and more powerful special-purpose reactors may ultimately be built. This reactor is of particular interest to the Air Force since it represents the boldest step into the unknown which we now dare to take, moving in the direction of compact, high-radiation density reactors which must ultimately be developed if the Air Force needs are to be satisfied.

(*b*) The second reactor is a land-based prototype of a reactor for use in propelling naval vessels. It would be a simple, single-purpose reactor designed specifically and solely for the purpose of producing large amounts of heat, under conditions which will permit conversion to propulsive power.

(*c*) The third reactor is a single-purpose experimental reactor designed specifically to give us information about the breeding process. This reactor at the present time is the most likely to demonstrate the actual breeding of new fissionable material. It is, however, neither a high-power reactor nor designed for the purpose of demonstrating appreciable amounts of useful power though an incidental amount of power may be produced by a byproduct.

(*d*) The fourth reactor is the more ambitious project, the Knolls Atomic Power Laboratory reactor. This reactor is intended to produce a really significant amount of electric power. At the same time, it is hoped that this reactor will be able to demonstrate at least partial success in breeding. This reactor is, therefore, a very complex device since its design represents a compromise between the demands for power production and for breeding. If successful, however, this reactor would represent a major step forward in the direction of the production of useful power without depleting, and perhaps even increasing, our national supply of fissionable material for any purpose.

Whether by accident or by design, this program is a reasonable middle-of-the-road program. It represents a balance between reactors contributing to the solution of military and civilian problems, a balance between reactors which use up fissionable material and reactors which promise to replenish or increase our national supply of fissionable material, a balance between a bold attempt to solve immediate problems by the engineering approach as in the Navy reactor and the intermediate breeder, and the more long-term research approach of gaining more information about the behavior of materials under novel, but controllable, conditions as in the materials-testing reactor, and the experimental fast neutron breeder.

I would like now to comment on the fourth requirement which I mentioned above, and which was concerned with getting value received for money invested. How does one put a money value on any new developments, particularly on one of a military nature? What, for example, would have been the value of the *Merrimac* to the South had not the *Monitor* come along? What was the value of the *Monitor* to the North in 1862 dollars? If we want to be modern, what

was the value of the *Spitfire* in the Battle of Britain, or what is the current value of an atomic bomb?

We have heard much discussion recently on the cost of producing atom bombs, but what are they really worth to us—in dollars? It would be helpful to have at least a rough estimate of the present value of an A-bomb, either in dollars or in equivalent divisions or battleships, or air groups. While this may sound difficult, order of magnitude engineering estimates to keep our thinking straight are not too hard to make.

We know, for example, that at the end of the war, our daily war expenses were approaching $300 million per day. If the A-bombs shortened the war by even 10 days, the entire $2,500,000,000, cost of the Manhattan effort can be written off, and recorded, as a spectacular success, and a *value*, as contrasted to *cost*, of at least $1,500,000,000 each to set on the Hiroshima and Nagasaki bombs.

Since warfare seems to be mainly a competitive destruction, we can get another estimate in an entirely different way. Taking the radius of destruction for a bomb as from 1 to 2 miles, the area destroyed would be approximately 6 square miles. In an average city the property value runs perhaps $50,000,000 per square mile. The destruction per bomb, therefore, represents about $300,000,000, and gives a figure of the advantage to us, and therefore of the value to us, in this insane competition in destructiveness.

We can approach the problem in another way to get another independent estimate. I have heard that a man by the name of Churchill, who seems to have a reputation in these matters, has stated that, but for the A-bomb, world war III would have been under way. Now for those who know how many bombs we have, it should not be too difficult to prorate the annual estimated cost of this war among the bombs on hand.

Finally, let us approach the problem in still another way, using an infantile form of operations research. We have been told that one A-bomb is equivalent in effect to 20,000 tons of TNT. Since big, single bursts overkill at the center, let us cut this by some suitable factor, say 10, for example. Now one of our large bombers can carry a pay load of about 10 tons, therefore, to carry 2,000 tons would require 200 planes. This is unassailably accurate arithmetic. Large bombers cost half a million dollars to build, but with logistic support, more like $2,000,000 in combat. One A-bomb makes 1 bomber the equivalent of 200. Ergo, one bomb is worth $400,000,000.

There is another conclusion which can be drawn from this quick operations research calculation. We should think twice or maybe even three times before permitting too casual diversions of material from the stockpile, even for other conceivable military uses. It follows also that civilian power will remain "pie in the sky" unless by a "break" in the breeder program or some other solution to the raw material problem, a more ample supply of fissionable material can be provided. Finally, it follows that this is indeed a game in which if we are to play at all, we play with "blue chips."

In the reactor field what would the nuclear-powered air equivalent of the *Merrimac* be worth in a future contest against a fleet of chemically fueled airplanes? What would a nuclear-powered naval vessel be worth in a future engagement if it were—as the *Merrimac* and *Monitor* were—one whole generation ahead of the conventional fleets of the day? What would be the value to the Nation if, as has been suggested, atomic energy could be used to evaporate sea water to make the deserts bloom? These are the really fundamental questions, and I am glad that it is Congress' responsibility and not mine to make decisions on them. It is, however, my responsibility to see that we get value received out of each dollar which is appropriated for the reactor program, and this will require more than anything else that effort be kept commensurate with both priority and promise.

I would like, therefore, in view of its special interest to this group, to return to the aircraft-propulsion reactor to consider it more in detail. To this group, fully aware of the serious limitations of chemical fuels, I feel sure that the desirability of an ideal nuclear power plant for aircraft is obvious. I can, however, quote a congressional report on the subject. In the Brewster report we find the following statement:

"In the event of war or in any international situation likely to lead to war, nuclear energy for the propulsion of aircraft would be comparable in significance to the atomic bomb itself. Presently known limitations inherent in all chemical fuels make difficult the delivery by air of atomic bombs against a distant enemy. Therefore, if the United States had nuclear energy propulsion in addition to atomic bombs, it would be the dominant factor in maintaining world peace.

Until these ends are attained, the United States must depend on military weapons and techniques currently available."

With the desirability of an ideal solution to this problem there is general agreement. There is agreement, too, in regard to the contention that developing any kind of an aircraft reactor will be extremely difficult. The NEPA project, carried out by the Fairchild Co., under an Air Force contract, has been engaged in a vigorous attack on this problem since 1945. The North American Aviation Co. and the Rand project have also made important contributions. These studies all seem to indicate that, granting the difficulties of the reactor problem itself, the power-conversion problem represents a challenge of almost equal magnitude.

As seems to be characteristic of this field of activity, anything which is obviously desirable and important seems to be almost incredibly difficult. To help resolve the impassé, the Commission last year made a contract with the Massachusetts Institute of Technology to make a study of the problem and to come up with recommendations. The result of this study was the Lexington report, the details of which are at present quite properly highly classified.

The immediate course of action indicated in the Lexington report is essentially that the aircraft-propulsion project should be continued in an intensive study phase, both theoretically and experimental, for the next 2 or 3 years, by which time it might be hoped that data might become available to permit a reevaluation and a more decisive conclusion. It is recognized that this study phase should be made national in scope to include the NACA and AEC as well as the National Military Establishment.

These are eminently sound guideposts and they are being followed. An ad hoc committee, consisting of representatives of the Air Force, Bureau of Aeronautics, NACA, and AEC, has been meeting since last January to coordinate the work of the various Government agencies involved and to insure an industry-wide approach to the technical problems. In such a joint attack on a problem clearly there will be some duplication which must be eliminated and some shifts of emphasis which somehow must be consummated. Committee procedures grind slowly but this work is well under way. Many of the companies represented here tonight have recently contributed technical talent to the national effort now being organized.

In the meantime, in accordance with the Lexington project recommendations the NME has been asked to evaluate the military worth of the proposed weapon if and when it is produced. This is a really tough assignment. It is indeed controversial, but not in the sense of an interservice feud. This is definitely not an Air Force versus Navy issue. Both the Air Force and the Bureau of Aeronautics want nuclear-powered airplanes if at all possible, and so long as the Atomic Energy Act is in existence neither can hope to build a private empire in this field even if it so desired. The issue, and the controversy is really a fundamental one. It rests on the typical, perplexing, circular, hen and the egg, nature of all the decisions involving new weapons which the military are continuously asked to make. How valuable nuclear-powered aircraft might be depends heavily upon when it will be available, what the maintenance problems are, what the cost will be in diversion of fissionable material, not only for the aircraft reactors installed, but also for the inventory required by the complex reprocessing procedures required for nuclear fuels. Unfortunately, the answers to these questions depend on the priority which is attached to the development program. How soon nuclear-powered aircraft can be available depends on how much effort we put into the program. Similarly, how soon we can give information as to probable performance and costs will depend on how rapidly the work progresses. The dilemma is very real and very serious. It was to aid in solving just such problems that the Weapons Systems Evaluation Group, under General Hull, was set up in the National Military Establishment.

The best summary of the situation which I can give is that the pessimists, who in general are those best informed, have thought through the immediate reactor and power-transfer problems and are staggered by the maintenance-and-operations problems which would be involved if the actual aircraft-propulsion devices for combat use were to be based on our present knowledge and practices. The optimists on the other hand either are not yet aware of the very real immediate difficulties, or they are betting heavily on new ideas and new developments arising during the course of the work which avoid some of the currently foreseeable troubles. In this connection, I seem to recall, however, that not many years ago all the technical facts, and all the arguments of the experts, indicated an upper limit of 100,000 pounds as an absolute ceiling for

the size of heavier-than-air craft. This is an area in which it will no doubt be wise for us to be open-minded but skeptical. The best we can hope for in a program such as this is one in which the best available advice is sought and used.

In my introduction I raised the question as to whether our objective was worth while and whether we had a sound approach. Let me now try to summarize the situation as it looks at the present time.

We want to maintain technical leadership in the atomic energy field. This is our objective and our assignment by act of Congress. As part of this effort we want a vigorous reactor program. This program must earn its keep for either peace or war purposes. The initial part of this program is the same whether the ultimate use of the reactors developed is civilian or military. We have a generously supported applied research program in the large national laboratories, to give us basic information for new developments and for providing a trained cadre of specialists in the atomic energy field. We have engineering task forces attacking some of the most promising possibilities available to us at the present time. Most urgent are the two premium fuel uses of interest to the miliary, namely, power for ships and power for aircraft. The first of these while difficult, can conceivably be attained by direct frontal attack. The second is being attacked indirectly with the materials testing reactor, representing an important, exploratory advance as well as providing an almost essential research tool. The MTR will be to reactor development what wind tunnels are to aircraft developments.

Another strong task force is engaged in a difficult but promising assignment on a reactor which can either be considered as giving power with fissionable material as a byproduct or fissionable material with power as a byproduct. In either case success would represent a major step in advance toward economical power for either military or civilian use.

The fourth task force is engaged in a frontal attack on the problems presented by the chronically short supply of fissionable material. Ideal success would increase by a factor of 139 the potential stockpile of fissionable material and might bring atomic energy for civilian use within sight. Even very partial success might go far toward helping us increase the efficiency of present production processes.

Success in all of these task force efforts is probably too much to hope for, but the possible return in each appears high enough so that success in one will pay for the rest. The risks are great but the stakes seem greater.

Details of the program are controversial and on these it is undoubtedly discreet for me to maintain a studied silence. I might be permitted, however, to end with a quotation from one of the wisest of scientists, Benjamin Franklin, which dates from the year 1780:

"The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which it may be carried, in a thousand years, the power of man over matter * * * Oh that moral science were in as fair a way of improvement."

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2. CURRENT STATUS AND PROBLEMS OF THE ATOMIC ENERGY COMMISSION'S REACTOR PROGRAM

Remarks Before Atomic Energy Symposium of American Institute of Chemical Engineers, Pittsburgh, Pa., December 6, 1949

This afternoon we are to hear some reports on technical problems involved in the Nation's atomic energy program. Before we listen to the technical experts, it might be helpful for me to try to summarize the status of the development of nuclear reactors by the Atomic Energy Commission, and outline a few of the broad problems, particularly those in the field of chemical engineering.

One problem arises from the glamorous nature of the subject itself. So much has been written about atomic—more properly nuclear—energy, it is small wonder that misconceptions and false hopes have arisen. For example, we frequently hear statements reporting that we will be able to use the energy in a thimbleful of water to drive the *Queen Mary* across the Atlantic. The energy is there—no question about that—but in spite of recent advances in the atomic energy art, no way is known of extracting this energy from so small an amount of fuel.

You will hear this afternoon about a fundamental concept called the critical size. The significance of this concept lies in the fact that a certain minimum amount of material is required before any nuclear chain reaction can proceed. This minimum or critical size happens to be quite large, certainly large compared to a thimble. To critical size must be added enough shielding to make reactors safe, and the amount of shielding required, according to present knowledge, is of considerable volume and weight. As a result, the machines for extracting atomic energy are all necessarily of relatively large size. This, in turn, limits the applications to those in which power is used in correspondingly large amounts. Thus, atomic-powered automobiles, sewing machines and household gadgets should be promptly eliminated from our thinking.

The large electric power plants supplying our cities and atomic power reactors would seem to be of more nearly comparable size. However, this does not mean that cheap electric power from atomic sources is assured. The money the consumer pays for electricity goes largely to cover costs of distribution. Relatively, the cost of the coal or other fuel is small. Therefore, since atomic energy promises further reduction in fuel costs only, it is clear that even successful power producing reactors could bring little, if any, immediate reduction in the cost of electric power to the consumer.

Another problem I should like to remind you of is that of the supply of nuclear fuel. There is a lot of uranium in the earth's crust but few concentrated deposits are yet known. A great search is going on for them, but up to now the world's total supply of high-grade uranium ore, the basic source of fuel for reactors, is definitely limited. Also of the total uranium naturally occurring, only one one-hundred-and-fortieth, that is, seven-tenths of 1 percent, is of the fissionable form, U–235. Thus, if atomic energy is to be developed as a power source, it appears that one of our first concerns should be to make use of the relatively large amount of nonfissionable U–238, as well as the fissionable U–235. The possibility of doing this with a "breeder" type of reactor is an attractive one and is a subject to which we shall return. Here we need only emphasize, that unless the breeding of new fuel becomes successful, the probability of civilian use of atomic power is dim. The difficulties we face are clearly large.

Why, then, do we worry and work at the development of new and better reactors? There are several answers to this question.

The first is that, even if the future holds nothing less dismal than the continued production of atom bombs, it behooves this Nation to keep in the forefront of reactor technology. At Hanford fissionable materials for atom bombs are produced in great nuclear reactors, and, sooner or later, the design of these reactors will become obsolete. Thus, with the present international atmosphere, a large fraction of the enormous cost of our reactor program must be charged to military necessity.

A second answer to the question, Why improve reactors? arises from the fact that there are times when the cheapness of power is not the controlling factor. I have never seen a figure for the cost per kilowatt-hour of the power used in a B–36 airplane. This in itself is evidence that no one really cares. Cost is not always the dominant factor. For example, even civilian operators would probably consider secondary the cost of electric power which can be provided close to a valuable mineral deposit that is remote from other power sources.

A third answer can be given by the line of reasoning that, although nuclear reactors are now extremely costly, the very newness of the technology and our very ignorance in this field indicate that these costs will certainly drop over the next several years. A corollary observation is that the cost of power produced from other sources appears to be following a continually rising trend. Thus, it is conceivable that sometime in the future the cost of atomic power, high though it be, will be less than the cost of power from other sources. Such facts account in part for statements by experts that the day of economic civilian atomic power is at least a decade or two away.

Fortunately, it makes little difference which of the three answers motivates us, the immediate actions that must be taken in reactor development are the same. The reactors now being built, or to be built soon, are all essentially experimental. They are designed for the knowledge to be gained from their building and operation rather than for the actual use of output.

The first phase of our reactor development program is the selection and design of the first "crop" of reactors. There are four of these. Let me name these reactors for you and give their purposes. It will be helpful to have this infor-

mation in mind as I later take up some of the chemical and chemical engineering problems involved. The four reactors on which attention is being focused are:

1. A materials testing reactor which, as its name indicates, will be used in studies of materials to be employed in building reactors;

2. A ship propulsion reactor, which is a land-based reactor designed as a prototype of a reactor for use in propelling submarines;

3. An experimental breeder reactor, which is for use primarily to explore the possibilities of breeding, that is, producing more fissionable material than is consumed. The reactor will operate with high energy, or fast, neutrons;

4. An intermediate power breeder reactor, which is designed to produce a significant amount of electric power and at the same time explore the possibilities of breeding. This reactor will operate in the intermediate energy range.

This four-reactor program crystallizes the best thinking the Nation has been able to muster on reactor problems since the end of the war. However, these are in no sense the only reactors which could be built. Indeed, many kinds of reactors are conceivable, and this fact in itself represents one of the major difficulties in formulating a rational reactor program.

It happens that I was closely associated with the country's guided missile work during and immediately after the war. The situation in the two fields is surprisingly similar. In fact, when I entered, or rather reentered, the nuclear reactor field, I had the feleing that "this is where I came in." In the guided missile business there was a saying after the war that every time three engineers got together with four bottles of beer, a new guided missile was born. The same statement might apply to the reactor field.

Reactors can be made to operate with slow, fast, or intermediate energy neutrons; at high, low, or medium temperatures; with half a dozen different moderators; with half a dozen different coolants; with mechanically rigid fuel elements; or with the fuel in solution. The number of conceivable reactors is determined by the many permutations and combinations of the above factors. It is small wonder, therefore, that each of many possible reactors has its strong following of protagonists.

The Commission made a great step forward when it obtained the recommendation of advising scientists that four, and only four, experimental reactors should be the initial goals of the Nation's program. Each reactor represents an undertaking of such difficulty that only by strong support behind each one, both in men and in money, can there be any likelihood of success. Diffusion of effort over too many reactors would almost certainly lead to disappointment and failure.

This program represents a balance between reactors contributing to the solution of military and civilian problems and a balance between reactors which use up fissionable material and reactors which promise to replenish or increase our national supply of fissionable material. It represents also a balance between a bold attempt to solve immediate problems by the engineering approach, as in the Navy submarine reactor and the power-breeder, and the long-term research approach of gaining information about the behavior of materials under novel, but controllable conditions, as in the case of the materials-testing and fast neutron-breeding reactors.

We are now entering the second phase of the reactor development program, i. e., construction. This stage will extend over a considerable period of time. The fabrication of components and auxiliaries and the erection of structures for a reactor are complex and time-consuming. But we are on our way.

The experimental fast breeder reactor is farthest along. Nuclear design by the Argonne National Laboratory has been completed, and architect-engineering design work by the Austin Co. of Cleveland, Ohio, is more than 90-percent complete. The Bechtel Corp. of San Francisco has been selected as the construction contractor. Installation of utilities, excavation work, and construction of an access road is already under way for this reactor at the Nation's new reactor testing station in Idaho.

The materials-testing reactor, which is also to be located at the reactor-testing station, is following close behind. Scientific design has been completed jointly by the Argonne National Laboratory and the Oak Ridge National Laboratory. Detailed engineering design is being done currently in Pittsburgh by the Chemical Plants Division of Blaw-Knox. Construction is expected to begin in the spring.

For the ship propulsion reactor, engineering and development work is being carried out at Argonne and at the Westinghouse Atomic Power Division on the

site of the old Bettis Airport near Pittsburgh, and detailed engineering design is scheduled to begin in about a year. Construction should be under way by 1952. The reactor will be built at the reactor-testing station.

As to the intermediate power-breeder reactor, engineering design work has been pushed to an advanced stage by the General Electric Co. The reactor is planned for construction at the West Milton, N. Y., site of the Knolls Atomic Power Laboratory near Schenectady. Preliminary site work, now under way, is expected to be completed in time for construction of major facilities to begin early in the 1950 construction season.

I would now like to return to the question of "breeding." You have noted that, of the four reactors, two are breeders and two are nonbreeders. The nonbreeders are pointed essentially toward power production. The breeder reactors represent a more subtle concept and one which I think will be of exceptional interest to a professional group in your field.

The breeding process consists of the production of fissionable material in a reactor in greater amount than is used up in the fission process which keeps the reactor operating. Our hope is for the breeding of substantially more fissionable material than is consumed as fuel; hence the label "Operation Bootstrap." In spite of implications, breeding is not akin to perpetual motion, though it is almost as intriguing. The promise is that by feeding a reactor the relatively more abundant but nonfissionable U–238 it may be possible to keep the reactor almost indefinitley supplied with fuel. Yet there is no magic or mystery involved; the success of the breeding process depends directly on the extent to which we can reduce neutron losses.

Uranium happens to come in nature in two forms, differing only in atomic weight; namely, U–238 and U–235. Only the U–235 is fissionable. By the fission of U–235 in a reactor containing both U–235 and U–238, excess neutrons released in the fission of U–235 may be captured by the U–238 and, as a result of the capture, convert U–238 into the fissionable new element, plutonium.

This is the process of the Hanford reactors. The important point is that less plutonium is formed than there was U–235 in the first place. In other words, in the Hanford reactors, there is a net loss of fissionable material. Only part of the energy originally available in the U–235 ends up in plutonium which can be used for bombs or other purposes; the rest of the energy is wasted.

Now, in each fission process between two and three neutrons are emitted. One of these neutrons is required to replace the original neutron and maintain the chain reaction. Another is captured by U–238 with the resultant creation of a plutonium atom. Then, we still on the average have a fraction of a neutron available to take care of leakage and losses. Such a reactor would be an ideal "converter" because, at the end of the experiment, there would be one atom of plutonium created for every atom of U–235 destroyed. However, since we are allowing a fraction of a neutron per fission for losses, if these losses could be reduced still further, we would end up with more than one fissionable plutonium atom for each fissionable U–235 atom. That would put "profit" into the operation.

We are still dealing with a converter, however, for we are converting from U–235 to plutonium. Ultimately we will get enough plutonium to build a new reactor using this element as a fuel. Now, the real breeding process can start. Beginning with a given amount of fissionable plutonium, if we produce more plutonium than we use up, the longer we run the more plutonium we will find in the reactor, as long as—and this is the important point—there is an adequate reserve supply of the nonfissionable U–238 available. This is certainly not perpetual motion. We are merely converting unusable U–238 into usable fissionable plutonium. However, this is no mean achievement, for the supply of U–238 is 140 times as great as that of U–235. The rate of augmentation of our supply promises to be very slow at best, but we are increasing the potentially available supply of fissionable material—the potential atom bomb stockpile, if you like—by a factor of 140. This is a goal worth shooting at.

Our difficulties are not over, however, if in the reactor itself the breeding process is successful. There remains the problem of reprocessing the fuel elements themselves. As you gentlemen are aware, fission products, radioactive elements in the neighborhood of barium in the periodic table, are formed in the fission process. These are the ashes of the reaction which, in sufficient accumulation, tend to smother the fire. Every so often the fuel elements must be removed from the reactor, chemically purified to remove fission products, refabricated, and reinserted into the reactor. The losses in this chemical processing are just as effective in reducing our "profit" as the losses of the neutrons themselves. The key question, therefore, is: Can the total losses, both of

neutrons and in chemical processing, be kept sufficiently low so that in a complete cycle there is a net gain?

Here is where the chemical engineer comes in, and here, I would say, we are getting a glimpse of the nature of a new front opening up in the campaign for reactor development. The problem of fuel reprocessing is an enormous one, and it is almost entirely a chemical engineering problem. The cost of this processing is so high that, even if all other costs in the reactor business were kept low, it alone might keep power derived from nuclear reactors from competing economically with other fuels. It pains me as an engineer to see carefully fabricated and machined parts, products of many man-hours of highly skilled work, casually dissolved in acid to start the chemical purification. This procedure is even more painful to chemical engineers, so they have been suggesting reactor designs in which the laborious fuel-element fabrication step can be eliminated either by placing the fuel in a solution or by utilizing techniques of transporting fluidized solids.

From such thinking there emerges the possibility of a new kind of reactor called the homogeneous reactor. All reactors constructed so far, except for one small experimental unit, have been built upon the principle of embedding fuel elements in other materials used for cooling, reflecting, and moderating. The question has been studied and restudied from time to time to see whether it would be feasible and practical to make a reactor in which these constituents are mixed together uniformly; hence the term "homogeneous reactor."

The homogeneous reactor, in its various conceivable forms, opens up entirely new vistas and areas of development in the field of reactor design. It is my belief that with experience from the first four reactors under our belts we should be in a position to attack this difficult new design and this new type will constitute a large part of the next crop of reactors. Obviously, chemical engineering must contribute heavily. We must come to grips with the fuel reprocessing problems involved in the operation of the first four reactors, and begin to take advantage of the opportunities which exist in the homogeneous design.

With so many chemical problems in front of us and development in prospect, it has long appeared to me that the Commission's reactor development program would require the strong guiding hand of a recognized professional chemical engineer. I am glad to be able to announce that, through generous cooperation of the University of Michigan, arrangements have been concluded for such a man to join our staff in Washington. As of this date, Prof. George Granger Brown, chairman of the department of chemical engineering and metallurgy at the university, has been appointed Director of Engineering in the Division of Reactor Development of the Atomic Energy Commission, on a leave of absence from his university.

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3. PROBLEMS IN THE APPLICATION OF ATOMIC ENERGY

Remarks before the Society of Automotive Engineers, Detroit Section, Detroit, Mich., May 23, 1950

Reactors are the machines for converting atomic energy, or more accurately nuclear energy, into forms which can be turned to useful purposes. Reactors are large, complicated, expensive, and controversial. Nuclear reactors provide man with the most concentrated energy source thus far devised and, in imagination, at least, have potentially unlimited possibilities. Reactors have been proposed for uses ranging from performance of the world's drudgery to the powering of rockets for space travel. While some of the proposed uses of reactors are strictly figments of the imagination, reactors themselves are real. They are certainly worth more than a casual scrutiny by a group of engineers such as this. Let's go back and look at them in more detail.

Reactors are made by so arranging an aggregate of fissionable material that a controlled nuclear chain reaction can be maintained. The chain reaction in turn depends on the detailed nuclear properties of materials.

You will recall that in 1939 the process of fission in uranium was discovered. This discovery culminated an exciting decade in the field of physics during which much of the detailed structure and many of the mechanisms involved in the internal parts of the atom were deciphered.

For our purposes we can still think of an atom as a miniature solar system with the nucleus in the center and the electrons circulating around it as planets.

The atom as a whole is small, with a dimension of about 10^{-8} cm. The nucleus, the central core of the atom is, of course, much smaller—about 10^{-22} cm. in diameter. Within the nucleus we find most of the mass of the atom in the form of protons and neutrons, the protons having a positive electrical charge, while the neutrons as the name implies are neutral. I remind you of these details for two reasons: First, to emphasize the fact that an atom is composed mostly of empty space; and second, to identify the neutron, which is basic to the operation of reactors of any kind.

Now let us try to visualize a uranium atom. It is mostly empty space, it has a heavy concentrated nucleus composed of 92 protons and about 140 neutrons, and circulating around this nucleus at relatively large distances are the planetary electrons. These electrons are the now familiar electrons of our ordinary electrical circuits and radio tubes and need not concern us further. Our interest is in the nucleus.

Suppose now, that a single neutron somehow gets loose and comes cruising into a uranium atom much like a comet coming into our solar system. If its trajectory carries it close to the uranium nucleus, attractive forces will set up something analagous to tidal waves in the nucleus. In the case of an actual collision, oscillations might conceivably be set up which could become strong enough to cause disruption by splitting the uranium nucleus somewhere near the middle. For our purpose, this is all there is to the mysterious fiission process, and I give you this admittedly oversimplified description deliberately to counteract, at least partially, the aura of awe, mystery, and magic which seems to plague the subject of atomic energy.

I mentioned a few minutes ago that the uranium nucleus contained 92 protons and 140 neutrons, i. e., an excess of about 48 neutrons. If we think of these particles both protons and neutrons as composing essentially a liquid droplet and then visualize the fission or splitting process, it is not too unexpected to find a probability that there are a few neutrons left over. This is in fact what occurs and makes possible the chain reaction. One stray neutron produces a fission releasing two or more neutrons, each of which in turn may collide with uranium nuclei and produce still more neutrons and so on ad infinitum. If this chain reaction is uncontrolled, we have an atom-bomb explosion. If it is controlled, we have a reactor.

Let us now consider the energy relations involved. As you know, the energy which is released in a chemical reaction involves only the energies of the outermost planetary electrons of an atom. Such energies are measured by physicists and chemists in units of electron-volts in a manner entirely analagous to the engineers' measurements of energy in terms of foot-pounds. Chemical energy releases, per atom, are roughly 1 to 10 electron volts. The fission process involves the tremendous binding forces of the atomic nucleus, and releases, per atom, up to 200,000,000 electron volts of energy.

In more familiar terminology, the energy in 1 pound of fissionable uranium is equivalent to the energy in 2,600,000 pounds of coal or 360,000 gallons of gasoline. This is what makes the atomic-energy business so exciting. This also is what brings in the subsophomore slip-stick artist. If 1 pound of uranium is equivalent to 360,000 gallons of gasoline, 1/36,000 pounds or 1/2,000 ounce is equal to 10 gallons of gasoline. A pill, therefore, of 1/2,000 ounce dropped in the gas tank of our automobiles will presumably give performance equal to a tank full of gas.

Let us give this old chestnut a decent burial, but do it with the utmost dispatch. You will recall that we said the uranium atom was composed mostly of empty space. We also said that the neutron and the atomic nucleus were extremely small. We now ask: What is the probability that in traversing an atom, a neutron should collide with a nucleus?

On a linear scale the atom is 10^5 times larger than the nucleus, therefore on an area basis the ratio will be 10^5 squared or 10^{10}. Now, to a physicist, this is really not a very large number but, on the other hand, it is not exactly a piddling number either. Its significance in the present case can be brought out as follows: If the empty space in a uranium atom surrounding the nucleus is 10^{10} times larger than the nucleus itself, then the probability of a neutron colliding with the nucleus in traversing the atom is only 1 in 10^{10} and to insure a collision, it would be necessary, on the average, for the neutron to traverse 10^{10} atoms. An atom is pretty small as we all know, but even at 10^{-8} cms. per atom, 10^{10} atoms laid end to end would occupy 10^2 centimeters of space.

For the chain reaction to proceed, each neutron formed must collide with a uranium nucleus, and in order to so collide, the place of birth of the neutron

must be surrounded, according to these crude estimates by, say, from 10 to 100 centimeters of solid uranium metal. (Our pill has become at least a foot in diameter.)

Now obviously the atomic dimensions used are inaccurate and better figures are available, but two conclusions should be drawn from the above numerical exercise; first, there is such a concept as a minimum critical size or amount of fissionable material, below which a chain reaction, whether for bomb or power purposes, cannot proceed; second, exact values of atomic dimensions, ordinarily only of philosophical interest have become of great practical importance. A very, very small error in a figure for an atomic cross section may make all the difference between a devastated city and a dud.

Now, I said my figures were inaccurate. They are inaccurate in themselves, for security reasons, but they are not inaccurate in comparative relationships. I shall return repeatedly to the security problem for it represents a chronic complication in the reactor program, but first let us probe a little deeper into the question of the extraction of useful work from uranium.

We have indicated that it is possible to get the energy equivalent of 2,600,000 pounds of coal from 1 pound of fissionable uranium. One of the limitations, however, which we have found lies in the concept of critical size. What are the other limitations? We can sketch them briefly. Let us consider shielding. In the fission process, many other radiations besides neutrons are released. There are alpha, beta, and gamma radiations as well as X-rays. In large doses, all these radiations are harmful and indeed dangerous. It is of primary concern, therefore, that reactors be adequately shielded in the same sense that powerful modern X-ray tubes are shielded in our hospitals. For reactors, however, because of their large inherent power concentrations, it is found that something like 6 feet of concrete or its equivalent is usually necessary for adequate shielding. Our pill has thus grown to a radius of many centimeters, and now in addition, is packaged with a wrapping of 6 feet of concrete. Drop that in your gas tank if you can.

Another limitation lies in the materials of which the reactor must be built. This applies both to the fuel elements themselves and to the structural materials of the reactor. Any group of automotive engineers is particularly well qualified to appreciate materials problems. The Atomic Energy Commission has in fact turned to some of you for help with its materials problems. The trouble is, however, that none of the materials that you people know so well seems to be of much help to us in the reactor business.

Our situation has been aptly described by one of the materials experts attached to the Commission staff, who is especially gifted in expressing himself. Referring to uranimum and its physical properties, he states and I quote: "Below 660° C. uranium is found in the orthorhombic form. This orthorhombic form of uranium is an unusual crystal structure for metals. One glance at it indicates to the trained eye that it will be anisotropic. And this turns out to be correct. It is anisotropic with respect to both physical and thermal properties. In addition, its thermal conductivity is low. This model of a single crystal gives some idea of the odd slip properties to be expected since the probable best slip plane is similar to that one might picture obtaining by drawing two corrugated sheets, one over the other. * * *"

After more in this vein, this authority states: "Any good industrial physical metallurgist would have a quick answer for our woes. After making a brief study of the crystal structure and properties of uranium, he would immediately abandon the material and recommend positively that his company use a substitute."

Now you see where this leaves us in the reactor business. From a fabrication standpoint, we don't like uranium but it does have the unique property of being fissionable so we have to put up with it. This statement is not quite true. We do have the artificially produced trans-uranic element—plutonium—which is fissionable, and might be considered for our reactor. On this element I would like to quote the same authority in what he says is a complete report on our knowledge of the physical and thermal properties of plutonium. I quote: "Plutonium is a very dense metal."

With this as our foundation, we are trying to build a multimillion-dollar industry on which a fair proportion of our military security is beginning to rest. Our materials problems do not end with the fuel elements, however. All the materials involved in a reactor are subjected to an intense bombardment of radiations of various kinds, and, to varying degrees, are subject to radiation damage. This consists of progressive changes in both physical properties and di-

mensions, changes the significance of which as mechanical engineers, you are in a position fully to appreciate.

There are still more limitations, however, on the materials we can use. All elements to a greater or less degree capture neutrons, and are being themselves transmuted into radioactive isotopes in the process. Since all possible neutrons are needed to maintain the chain reaction, all such parasitic captures operate to the detriment of the efficiency of the reactor as a whole. Many elements which might otherwise have desirable or at least tolerable properties are eliminated by this additional requirement. Finally there is the temperature limitation. One of the presumed virtues of a nuclear reaction is that, in contrast to chemical reactions, there is, for practical purposes, no upper limit to the temperatures which can be attained. A Carnot-cycle operating between a million degrees centagrade and room temperature might be a heat-engine designer's dream, but unfortunately, our materials limitations trip us up again. In practice we are constrained to design reactors for operation at a prosaic several hundred degrees centigrade, even as does the designer of the lowly chemically-fueled heat engines.

Assuming, however, that the shielding and materials problems can ultimately be solved, there still remains a problem very basic to the whole reactor program and this is the supply and cost of fissionable material. Especially in view of high military demands for fissionable material for A-bombs, it is conceivable that there will be little left over even for military mobile power units, let alone for civilian power installations competing, or trying to compete, with coal and water power. As usual in this strange business we skirt the borderline of military security in trying to find answers to our questions, but it is not necessary to compromise restricted information to gain a broad perspective on our problem.

From open literature and figures internationally available before the war, we can get estimates of the then known uranium ore reserves as well as the reserves of coal and petroleum. To me, in order to get some basis for facing up to the question of whether there is any sense in building reactors at all or not, it is helpful to note the following comparison. Remembering that one pound of uranium is equivalent to 2,600,000 pounds of coal or 360,000 gallons of petroleum, we can convert all these fuel supplies into equivalent energy units. We then find that in these equivalent energy units the energy reserves in the uranium is about 10 times *greater* than that in petroleum, though 100 or more times *less* than that in coal. Note that I did not say that the reserves of uranium are greaer than those of petroleum. I said that the *energy in* the reserves of uranium are greater than the energy in the reserves of petroleum. This comparison gives us our calibration, so to speak, and suggests that atomic energy is potentially at least considerably more than a scientific curiosity, or for that matter, even more than a highly specialized munition of war.

In this comparison, however, we have tacitly assumed that all minable uranium is available for conversion into useful energy. Since uranium occurs in nature in two forms, only one of which is fissionable, we are implying in this comparison a solution to the problem of converting the unusable form into usable fissionable form. The problem is known as the breeding problem and the importance of finding a solution to this breeding problem is indicated by the fact that the presently unusable form of uranium is 140 times as prevalent as the usable fiissionable form. The long-term outlook for useful atomic power would be dim indeed without the ultimate solution of the breeding problem, and the Commission can be expected, therefore, to continue to support vigorously experiments on breeding.

So far we have learned then that though difficulties are many, and development costs are bound to be high, we can produce energy in the form of heat from fissionable material by the use of reactors and, further, we have learned that the total energy available and awaiting conversion is sufficiently great to have a bearing on world economy. It does not follow that all that is needed to prove atomic power practical is a demonstration that the heat which we already know how to generate can be converted to mechanical energy in the form of turning wheels or electrical energy to light electric bulbs.

There is an enormous reserve of potential power in tides, for example, and the theory of water wheels has been known since the time of Archimedes. There were no really difficult engineering problems in the Passamaquoddy project, certainly nothing approaching our reactor materials problems, and yet the Passamaquoddy project was dropped. Similarly, there is a potentially unlimited reserve of power in winds, and the theory of windmills is fairly well understood. Yet, we have no appreciable contribution to our national

energy reserves from this source. Now the question can be asked. Is tide power and wind power practical? The answer depends on what we mean by practical. Here we become involved in semantics. To the layman, to be practical seems to mean, for example, that a machine really works, that the wheels actually turn in fact as well as in theory. To an engineer, to be practical means that a machine must not only work but it must work economically. And still more specifically it must work economically somewhere.

Recently I read a magazine article which implied that what the Commission ought to do in the reactor program was to demonstrate promptly that atomic energy for civilian power was practical. Here we are back in semantics again. If "practical" is meant in the layman sense, then such a demonstration is pointless, for any one of you engineers could calculate the available mechanical energy once we reactor people give you heat quantities and temperatures. If, on the other hand, the word "practical" in this magazine article was used in the engineering sense, then such a demonstration is beyond the powers of even such an august body as the Atomic Energy Commission. Cost factors, as you engineers know, have a way of being geared to natural laws, and cost savings can be made only after a long and painstaking process of learning more about these laws. Once the laws are understood, ingenuity can be exercised to cut costs by, however, a closer cooperation with nature and not by circumventing her laws. Thus, it is with reactors. We know that they work. We also know that they are not economical. No act of volition on the part of the Government can by itself make reactors economical. The most the Government can do is to devise means whereby incentive is provided for the studies necessary to introduce the possible savings.

It would no doubt be of interest to this group to learn how far we have come and how far we still have to go along the road to economical power. Again, we must be mindful of security for, while this Nation which is frankly stockpiling atom bombs has an enlightened policy of making periodic reports to the world of as many of its atomic activities as possible, by some strange paradox other nations which purport to be interested only in peaceful uses of atomic energy have yet to publish and share with the world a report even remotely approaching the equivalent of our Smyth report.

Without revealing new data, however, we can collect for you some figures which will begin to show what the economics of atomic energy really are. As engineers, we all learned long ago that it is useless, even futile and foolish, to be afraid of facts.

First to assist in cutting through the underbrush, let us assume that the cost of uranium fuel is zero, that peace unexpectedly breaks out and that fissionable material is available as war surplus. Then reminding you again that all we produce in a reactor is heat, you will note that all we can replace with nuclear energy components in the conventional steam power plant is the fire box and boiler. All the heat transfer apparatus, the turbines, the generators, and the distribution system remain the same. In this regard, a rough figure to carry in mind is that even if power could be put on the bus bars at the central station at zero cost, the costs of distribution are such that the cost to the consumer would be reduced only by 25 to 35 percent. The fondest hopes for civilian atomic energy must therefore be expected to produce savings somewhat less than this and can hardly be expected to be really revolutionary.

In somewhat more detail, costs of power from a typical coal burning power plant are roughly as follows:

Plant cost per kilowatt of installed capacity	$133
Annual cost per kilowatt of installed capacity	56
Interest	4
Fuel	30
Other operating costs	22

These costs are well known in the industry and can be made available with any degree of refinement that may be necessary. It is when we come to try to estimate the costs of atomic energy that we run into trouble. In the first place, very little information exists. In the second place, this little information must be handled very circumspectly on military security grounds. These are quite legitimate restrictions, for if costs of reactors are given in appropriation hearings and dollars per kilowatt in speeches like this, it does not require too much imagination to combine the figures and get total power in production reactors, thus inadvertently revealing our production rates of fissionable material.

Avoiding, however, any reference to production reactors, and realizing full well that research reactors will, in general, be considerably more expensive than one designed solely for the production of power, we can at least get a figure with more significance than the purely hypothetical ones which have been used. To be on the safe side securitywise, suppose you let me average four unspecified but large research reactors. The figure comes out $2,688 per kilowatt of power, and therefore, assuming 25 percent conversion efficiency, $11,752 per kilowatt of electrical power capacity. This is the figure for atomic energy costs which, whether we like it or not, we must compare with a figure of $100 to $200 for corresponding capital investment for coal-fired steam plants.

Now, lest we be misled by figures taken from research reactors, let us see what can be concluded from figures internationally available on mobile power reactors. From the Encyclopedia or Janes Fighting Ships, we can guess maximum power for a modern submarine as 25,000 shaft horsepower, or, say 18,000 kilowatts. From the appropriation hearings and news releases we note the cost of the proposed Navy reactor to be estimated at $25,000,000. This gives a figure for the reactor capital cost of about $14,000 per kilowatt. We can at least conclude therefore that it is not only research reactors which are expensive. Now these figures are rough, deliberately rough, but they begin to give a basis which can help to keep our national thinking straight.

Further details would be desirable but perhaps enough has been given to indicate the nature of the job ahead and to suggest the kind of time scale which must be allowed for in our thinking. We must be prepared for a long, hard pull. As Chairman Pike expressed it a few weeks ago, the reactor development program is one which private industry would be foolish to undertake, and the Government would be foolish not to undertake. How, then, are we going about this assignment?

We have, as most of you know from the newspapers, a reactor construction program consisting of four specific reactors of novel design intended to give actual experience with the construction and operation of these devices.

These reactors are:

1. A *materials testing reactor*, designed for the highest neutron flux yet attempted. As its name indicates, it will be used in the development of other reactors. Construction is just starting.

2. A *ship propulsion reactor* which is to be a land-based prototype of a reactor for propelling submarines, is being designed to operate in the slow neutron energy range with which we have had extensive experience. It is in advanced stages of engineering design.

3. An *experimental breeder reactor* designed primarily to explore the possibilities of breeding, that is, producing more fissionable material than is consumed. This reactor will operate in the high energy, or fast neutron energy range. We have one other reactor operating in this range. Construction is under way.

4. A *ship propulsion reactor* designed to operate in the intermediate neutron energy range, in which we have had no experience. This project, basically a power reactor, replaces an earlier project for an intermediate reactor for both power and breeding.

We have tried to keep this program of specific reactors a balanced one representing the needs and interests of various groups. Note that two of these reactors originally were breeders to assist in the solution of the long-term raw materials problems. We recognize the importance of stability, in a program such as this. Since last summer, however, a number of things have happened which could hardly be ignored and some reshuffling has occurred, the relative priorities of short-term military projects moving up relative to long-term purely civilian projects. In spite of these shifts in emphasis, all the reactor projects are moving along essentially on schedule except for the last one.

The planned power-breeder reactor at KAPL has been considered a casualty to the civilian cause in this readjustment. No doubt this is at least partially true. At the same time, however, the stage of reactor development being what it is, it would appear to be desirable to get *some* power, *somehow*, before worrying too much about how it is to be used, or before trying to make a dual-purpose reactor. If military needs are such that they can help to carry the staggering financial burden of development costs, I, for one, cannot look upon these needs as a threat to the atomic power program. On the contrary, the weight of the military demand will speed up the solution to some problems which must also be solved for a power reactor for civilian use.

With the above facts as background, let us now try to get an estimate of the situation in which we find ourselves. First, recall that atomic costs must come down by a factor of 10 or more before economical civilian power is even conceivable. In attacking this problem we can move forward in two ways. We can seek by ingenious new approaches to make major cuts in costs. This requires a bold program of basic research and support of radically new approaches to the reactor design problem.

Progress in research consists essentially of learning something from one's mistakes. Research does not thrive, therefore, in an atmosphere in which one dares not make a mistake.

There is little hope of cutting costs sufficiently by minor savings in mechanical design, by the elimination of a valve here and shortening a pipe there, etc. These are the savings that pay big dividends in quantity production but in the reactor business we are far from that stage yet. We must look for big savings.

The most promising, or most productive, direction we can go to make progress is to seek and to encourage uses for reactors where the economic factors are less compelling. In this approach the military pressures and demands work for us and not against us. In fact, the history of technological development is replete with examples of civilian devices, the development costs of which were borne by the military. Take such a lowly item as an aluminum saucepan. How long would it have taken to collect from housewives, in dimes and quarters, the millions of dollars that have gone into the study of the metallurgy and fabrication problems of aluminum. Or, take airplanes themselves. Would the Post Office Department, for example, have been able to find the hundreds of millions of dollars for the development costs of a device as visionary as the airplane was considered to be in the early days? Or, take iron and steel. Would the demands of the agriculture of the early 1700's have stimulated the researches in the metallurgy and fabrication methods of iron in its various forms which were pressed so vigorously by the armorers and ordnance experts of the time, and preceded by nearly a hundred years the industrial revolution?

It is entirely conceivable that the laws of nature may be such that reactors will follow the path taken by the development of the submarine which seems to have no civilian uses. We might well ask the question: Are submarines practical? A civilian would answer definitely "no," a naval officer with an equally definite "yes." Only time will tell whether power reactors are (*a*) practical at all; (*b*) practical for military purposes; or (*c*) practical for both military and civilian purposes. Even in the case of the submarine, which, contrary to the hopes of Simon Lake, has proved to be quite useless in the civilian economy, the by-products of the military development have made a profound contribution to our civilian daily life. To Detroit engineers, the history of the development of the Diesel engine is too well known to permit me to repeat it here. For the uninitiated, however, the point is that the lightweight Diesel engines, now replacing almost completely the familiar steam locomotive on our railroads, were developed specifically for naval use in a submarine.

Returning to the question of cutting costs of reactors, perhaps the most important contribution which could be made is to devise some mechanisms whereby a real incentive could be provided to keep costs down. We need the kind of incentive which historically has been given by industrial competition.

The application of this traditional American way of doing things to power reactor development is seriously hampered on two counts: the extraordinarily high costs of the development and the requirements for secrecy. This is a problem of major national concern, but we believe it can be solved.

Some of you already may have been called upon to devote some of your time and energies to our problems. I am confident that ways will be found to bring a far greater proportion of the Nation's technical resources to bear on the development of atomic energy. I am confident that as demands are made of the automotive industry, you will respond as promptly and effectively as you have in the past.

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4. REACTOR PROGRAM OF THE ATOMIC ENERGY COMMISSION

Remarks Before American Petroleum Institute, Los Angeles, Calif., November 15, 1950

There are few subjects about which there has been so much talk and so little said as about atomic power. Interest in the subject, for various reasons seems

to be so high that a few available bits and pieces of information get chewed over again and again as part of an effort to get public understanding of the subject. For various reasons, also, the emotional content of most presentations runs high and this adds little to the clarification of issues which is to be desired.

The American Petroleum Institute is fortunate in having had a series of excellent presentations on this subject at relatively long intervals. You have heard from Clark Goodman on this subject in 1945, from A. H. Compton in 1947, and some of you no doubt have read the more recent conclusions of Eugene Ayres as to this source of energy, in your proceedings. A field as ponderous and controversial as this one progresses slowly so the reports you have had have given you observations at roughly, 2-year intervals and this gives you a chance to concern yourselves with *trends* without too much concern for short-term oscillations created by personalities, political factors, or the impact of international crises. I will try my best, therefore, to give you a status report as to where we are now, will try to call your attention to trends which seem to me to be of significance and worth watching, and finally, to suggest the problems and issues which are emerging and will require attention at some future time.

We can classify most of our problems at the present time in two main categories, namely, technical, and economic. These I will discuss in turn.

TECHNICAL PROBLEMS

To date we have been almost exclusively preoccupied with problems in this category. You will recall that nuclear reactors are the machines for converting the energy available from the chain reaction into useful forms. Most dramatically, perhaps, the reactor is a slowed down and controlled atom bomb explosion. The technical problems involved are many and have frequently been described. For example, there are the problems of:

1. Materials to stand higher temperature than are attainable from chemical reactions.
2. Materials which show minimum radiation damage under the intense bombardment of neutrons, gamma rays, etc., in the interior of the reactor.
3. Materials which do not absorb and waste an excessive proportion of the available neutrons.
4. Shielding of personnel and instruments against the adverse effects of radiation.
5. Control gear with response times adequate for safety.
6. Heat transfer rates higher by an order of magnitude than those conventionally used.
7. The control of radioactive materials produced in the fission process and deposited with the fuel elements to the detriment of the neutron economy.
8. The handling and ultimate disposal of radioactive wastes in a manner which will constitute the minimum health hazard.

The difficulties involved in these problems have often been stressed and I will not belabor them further. The important point, however, is that it is with precisely these problems that our huge national laboratories have been preoccupied since 1945. Much progress has been made toward solution but, as in other applied research programs, just how much is difficult to assess without some full-scale trials.

This brings us to the second major phase of the current reactor program and that is the specific reactor projects. These, too, have been previously described in considerable detail but you will recall are four in number:

1. *A materials-testing reactor*, designed for the highest neutron flux yet attempted. As its name indicates, it will be used in the development of other reactors. Construction well advanced.

2. *A ship propulsion reactor* which is to be a land-based prototype of a reactor for propelling submarines, is being designed to operate in the slow neutron energy range with which we have had extensive experience. Construction is well under way.

3. *An experimental breeder reactor* designed primarily to explore the possibilities of breeding, that is, producing more fissionable material than is consumed. This reactor will operate in the high energy or fast neutron energy range. We have one other reactor operating in this range. Construction and fabrication is practically complete and installation is beginning.

4. *A ship propulsion reactor* designed to operate in the intermediate neutron energy range, in which we have had no experience. This project,

basically a power reactor, replaces an earlier project for an intermediate reactor for both power and breeding. This project is now in advanced stages of engineering design.

Most of these reactors were officially authorized for construction now nearly 2 years ago and several of them we note are well along the road toward completion. Progress on these reactors has a significance far beyond the contributions of the individual reactors themselves. Such progress gives us for the first time, since 1942, an objective measure of the "state of the art" in reactor technology. In general, progress has been slightly but not seriously behind schedule. My stock answer to queries in this regard is that the program is progressing slightly better than I expected but not as well as I had hoped. I'm sure some of you gentlemen can well appreciate the feeling behind that statement.

As technical people, however, the important thing to us is that I can report that the delays were not due to unforeseen and unexpected technical troubles. Our worst bottleneck, for example, has been the production in pure form and in ton quantities for structural purposes of a chemical element which, until a year ago, was essentially one of the curiosities lumped under the rare earths in the periodic table. To a technical man, a bottleneck of this kind isn't even interesting, it's only a damned nuisance. Other delays have been due to procurement difficulties in the case of essentially conventional items such as tanks, valves, pumps, etc. I fear that it is almost an occupational disease on the part of a scientist to focus attention on the part of a problem of particular interest to him and neglect what appears to him to be prosaic. I recall with some embarrassment, for example, my own experience during the early part of the last war, when we were successful in producing, in quantity, radio parts which could stand being fired out of cannon, but then absorbed a long delay while we tooled up, to machine in quantity, simple parts of ordinary steel.

In summary, then, so far as specific reactor projects are concerned, our laboratories seem to have done an adequate job of applied research, and to have provided our designers with adequate "handbook" type of data. Our designers in turn seem to have successfully avoided gross troubles of the type which might be uncovered early in a construction program. For a final and more detailed answer, we must wait until the present generation of reactors has been carried through the debugging stage and is in actual operation. We are, so to speak, on a "construction plateau" in our program; our bets are made, our resources committed. We can only await as philosophically as we can the final result. From what I read about the oil business, I gather that a number of you gentlemen occasionally go through a somewhat similar process.

So far we have been discussing technical problems in the current crop, the present generation of reactors. While we are stalled on the afore-mentioned construction plateau, it is not too surprising that there should be considerable discussion as to what types the next generation of reactors should include. Remember reactors are expensive. Small ones cost from $1 to $5 million; full-grown ones $25 to $50 million. Reactor designs are numerous. What with breeders and nonbreeders, high, low, and intermediate neutron energy, high, low, and medium temperatures, natural, slightly enriched, and highly enriched fuels, homogeneous and heterogeneous fuel distributions, assorted moderators, coolants, and corrosion-resisting coatings, the number of permutations and combinations runs high. The problem is not to invent a reactor. The problem is to select one which will yield maximum returns. I would like to quote your own Bob Wilson on the appraisal ratio for a research project:

"The appraisal ratio * * * is the product of the probable value to the company of a successful result, multiplied by the probable chance of success, and divided by the estimated cost of the research and development, not merely the research cost."

This is good advice and gives an excellent basis on which to assess our various possible reactor designs. But what, really and honestly, are our reactor *needs?* Before we can evaluate a promise to fill a need, we must be agreed on the need itself.

First, let us clear the air of some unnecessary confusion. Various articles state or imply that there is a great and immediate possibility of use for civilian atomic power which is being sabotaged by (*a*) the military, and (*b*) the private power interests. A Russian physicist, writing in the Moscow Literary Gazette, recently quoted in the Daily Worker, for example, claims that Americans "sabotage the peaceful use of atomic energy because it would outdate old machines

and make coal and oil valueless." If such statements contain even one iota of truth, then in my present position as Director of Reactor Development, I would expect to be a focal point for such pressures, but I can only report that in nearly 2 years they have failed to develop either from above or below. I can go further, since this is a free country, and urge these pressure groups to hurry to make their influence felt, lest decisions be made in the next few weeks without their help and contrary to their interest so that all their effort and work might be wasted. This would indeed be a shame.

In the meantime, let us return to our technical problem, namely, that of picking, in the national interest, the most promising reactor or groups of reactors. We *need* production reactors for producing fissionable material for either military or civilian use. We can probably *use to advantage* mobile power reactors if the cost in both dollars and fissionable material does not prove to be prohibitive. We can *justify* heavy commitments to reactors producing electric power only if and when the cost of this power bears a reasonable relationship to the cost under comparable conditions of power available from conventional fuels. These are the boundary conditions on our problem.

Now, which reactors should be built? To justify building an expensive reactor, we must, or should have, a *demonstrable need*. To assess the need we must know costs, but costs can only be determined by first building reactors. This is the circular argument in which we continually find ourselves. To break out of this vicious circle we have used the fact that, for the military needs, the unknown economic factor is less compelling.

We can draw a few other general conclusions from our reactor experience to date. For example, with fissionable material in great demand for bombs, we must concentrate on power reactors which, at least partially, replenish or replace the fissionable material used up. Mobile military reactors therefore converge on production reactors, and both should eventually be combined with breeding of new fuel, that is, the breeder reactor, which continues highly desirable. Furthermore, the civilian power reactors, precisely because of their need for the lowest possible cost of power produced, are tending to interlock with production processes and therefore production reactors for military uses. Thus, instead of being separable into neat little problems which can be solved, one at a time by themselves, the trend appears to be toward greater complexity with a pronounced interlock between production, mobile and civilian power reactors.

Note how insistently the economic factor intrudes itself into what we would like to consider as a purely technical problem. Let us therefore turn to the economic problem before trying to summarize the desiderata for the next generation of reactors.

ECONOMIC PROBLEMS

Critics of the American atomic-energy program invariably make the assumption that civilian atomic power could be made practical (i. e., cheap) and generally available if only those in authority had the will to do it. The assumption is that by another billion-dollar crash program, Manhattan District type of attack, the remaining necessary secrets could be uncovered and the real atomic era ushered in. Actually, there seems to be little in common between the atom-bomb problem and the civilian-power problem except the language. They differ in kind rather than in degree. The atom-bomb problem was almost uniquely a black-and-white problem. It was either a grand success or a colossal failure.

The civilian power problem is quite different. Enough technical facts have long been known to assure us that electric power can be produced if we are willing to pay the price. It is for this reason that the crash program approach is the last thing we want in the civilian power problem. If correct bookkeeping procedures were followed, the high costs of such a program would have to be charged to the power ultimately produced (vide Bob Wilson's formula), thus *raising* rather than lowering its cost. In many respects the economic factor makes the civilian power problem a tougher one than the atom-bomb problem and we will have to look elsewhere for an analogy. Perhaps the closest we can come is the problem of private flying for the airplane industry. Here, as in the case of civilian atomic power, the technical problems are already essentially solved at least to a first approximation. Until private flying becomes much, much cheaper, willing potential customers, like myself, for example, will continue to look upon private planes as an unjustifiable luxury. At the moment, civilian atomic power is similarly potentially available, but only as a luxury civilians can't afford.

SINGLE-PURPOSE POWER REACTORS

Figures in the literature on estimated costs for atomic energy vary by at least a factor of 10. I am not going to try at this time to give you more accurate cost figures for three very good reasons:

1. They do not exist even within the Atomic Energy Commission.
2. If they did exist, they could not be released for security reasons.
3. If they did exist and if they could be released, I wouldn't believe them anyway.

My pessimism in this matter stems from the fact that two variables are involved both of which are uncertain. As in other human activities, we must consider both the first cost and the upkeep. The first factor is still essentially unknown, for we have never even designed, much less built and operated, a reactor intended to deliver significant amounts of power economically. The second factor is even more uncertain since all fissionable material to date has been produced in a Government monopoly on a crash-program basis in such a way that precise cost allocation to any one item simply cannot be made.

The only really significant figure for the cost of civilian power from atomic energy would be one based on a power system which pays its own way with only civilian instead of military uses of byproducts, all the way from the uranium mines to the waste-disposal dump.

Even excepting the additional complications introduced by the security problem the situation in regard to cost estimates is quite unsatisfactory, both inside the Commission and in the open literature. The hearings of the Appropriations Committee are vivid testimony to the effect that in this business, estimates cannot be taken at face value and invariably turn out to be too low. It is for this reason that my own approach has been to set upper limits on cost based on the firmest available costs on the most nearly similar reactor either built or under construction. We cannot take too seriously estimates based on the cost of low-temperature-production reactors and the assumption that they can be redesigned for higher temperature operation. If this were easy to do it would have been done in the first place and, if it is not easy to do it is likely to be expensive. Thus I have been driven back to the ship-propulsion reactor as our currently best available yardstick for nuclear-power costs. A rough figure for this has been given as $1,400 per kilowatt-hour installed capacity for nuclear power, as against $133 for the corresponding equipment of a conventional power plant.

Now we know that while in a mature and highly competitive business such as the power industry, it will be slow work to reduce further the $133 figure, there are many savings which can be made in the $1,400 figure for the mobile nuclear power plant. Let me list some of the high-cost items where savings seem possible:

1. High development costs of a prototype reactor.
2. High costs for meeting naval requirements of weight and space.
3. High cost of reprocessing fuels.
4. Lack of volume production.
5. High costs introduced by extreme security precautions.
6. High costs introduced by extreme personnel safety precautions.

If with savings in these items, and the almost certain technical improvement in a field as new as atomic energy we can pick up a factor of two or three we are beginning to close in on the competitive figure of $133 for corresponding capital costs in the conventional installation.

To effect these savings, it has been my personal opinion that fastest progress would be made if we could move toward the design and construction of reactors on a competitive bid, fixed-price basis, or by otherwise utilizing a profit-making incentive. As in other major projects, this would require carefully written specifications covering, however, the hazard problem and the security problem in addition to the more conventional provisions. This will not be easy but I believe that ultimately it can be done if we in Washington have both the will and the ingenuity.

Turning to the fuel-cost problem, we can only emphasize that even for nuclear fuels this item is not negligible. Taking from the open literature the figure of $20 per gram for nuclear fuel as a basis, we still get a fuel cost of 1 mill per kilowatt-hour, as compared to 2 mills for chemical fuels. The $20 figure is almost certainly low and seems likely to increase as the supply of high-grade uranium ore runs out. For single purpose civilian power-producing reactors burning U–235, the conclusion still is then that for nuclear power the cost of fuel will be about the same as for conventional plants, while the cost of the installation (and

probably its operation) will be considerably higher. Exactly what the cost figures will be cannot be known until we find it possible to try the experiment.

There has been a noticeable increase in recent weeks in articles in the popular press on the imminence of industrial participation in the atomic-power field. By implication, it might be assumed that some major technical advance has been made, some new secret discovered which at long last will make civilian atomic power available in quantity. From the above, my remarks on the technical factors involved, it should be clear that there are no new elements in the technical picture which have suddenly made the possibility of civilian power more attractive and we must look elsewhere for the reasons underlying the greater interest in industrial participation both on the part of industry and the Commission.

MULTIPLE-PURPOSE REACTORS

So far I have talked mostly about reactors whose sole reason for existence was the production of power. But we have reactors producing plutonium which throw away their heat. Suppose this heat could be put to some useful purpose, say the production of power, or even the distillation of sea water? What then is the economic picture?

Here cost estimates are only rough, at present. But one thing is certain as you gentlemen know—utilization of byproducts can sometimes salvage a proposition originally not economically feasible. Now technically a reactor to produce both power and plutonium is not out of the realm of possibilities. We don't know much about such a reactor yet. But if we can make one work, the value of the plutonium would allow us to charge off much of the operating cost to the production of the plutonium, and might provide the power at reasonable costs.

Progress in the atomic-energy field has brought us to a point where we can see more clearly the real nature of the joint Government-industry effort that is required to realize the potential in atomic energy. In some respects, it is clear to us only in terms of problems to be solved. But those problems have been identified sufficiently for both the Commission and industry to determine the most effective role each must play.

The level has been substantially raised in our reservoir of technical knowledge. We have more tools with which to work, but our workload has increased even more. In the meantime, industry has expanded its competence in the field of atomic energy, and begins to see its own role in terms of something other than job contracts. It is the multiple-purpose reactor which holds the greatest promise of returns, both for the Government and for industry, and promise of the real benefits of atomic energy about which we have all been so hopeful.

The Commission, on its own part, must explore further procedures which will induce industry to carry heavier responsibilities in this field, which is the beginning of a new phase of the Commission's approach to its problems.

I think I can say with some confidence that it is this element rather than a new imminence of cheap civilian power which lies behind the increased interest on the part of industry in certain phases of the atomic energy business. It follows as a corollary that while in the immediate future there may be some maneuvering for position—that is, getting better prepared for active participation—on the part of various organizations, the predicted cutthroat competition and the show-down battle between the public and private power interests can still be regarded as being some distance in the future.

Suppose now that either out of its own laboratories or from industrial contractors we do get a design of a reactor producing plutonium and which yields electric power as a byproduct. Does this finally usher in the atomic era? I'm afraid not. The major charges will still be carried by the military need for plutonium. Only if and when we can produce fissionable material which when used for civilian power will pay for its own production costs can we truly say that the civilian atomic power problem has been solved. In the meantime we would be less than prudent if we did not take advantage of every opportunity to reduce over-all costs by an increasing emphasis on the use of byproducts, as has in the past been so successfully done by industry.

Assuming then that it is desirable to have greater industrial participation, and by this let us agree to mean responsible, cost-reducing, competitive participation, what are the problems which arise?

First and foremost there will be the problem of shortage of personnel. A recent IBM card run on our National scientific roster turned up a total of only 350 names in the whole country of people who list themselves either as mathematical physicists or as nuclear physicists. Of these, most will be engaged in

university teaching, others will be suspect "intellectual pinks," so it is not surprising that we count our experienced reactor designers almost on our fingers. Essentially all the remainder are already committed and over-committed by our present program, and nothing would cause more disruption in this program than an irresponsible uncontrolled proselyting of key personnel. This is a primary problem. Its solution will almost certainly lie in a training program on an expanded scale, for our embryonic industry.

A second very serious problem will be that of unpredictable costs which may be introduced at any time during operation by Government decree. These will be mainly in the fields of security, fissionable material accountability, and personnel safety both in and near the plant. In this field, initial agreements can probably be worked out, but abrupt and arbitrary changes in the rules of the game after the play is underway are going to raise interesting questions.

A third category of problems which can readily be foreseen is that toward which the industrial "market survey" is aimed. In other words, what is the future market for your product. As is well known, the Government is reluctant to commit itself in advance for expenditures in future years. Yet in a development as ponderous as that of atomic energy, and privately financed industrial approach would have to be based on firm plans for 5, 10, or more years in the future.

Another knotty problem is that of the fair and equitable distribution among many interested parties of the opportunity to play an active part in this field. In this regard, I recall the early days of radio when lawyers argued furiously that each citizen or group of citizens had a constitutional right to an equal share of the radio-frequency spectrum. The fact that the extent of the available spectrum was limited by natural law somehow did not seem to register.

Finally, there is the category of legal problems which can usually be solved with congressional action if necessary. In this case there are additional complications due to international implications in our United Nations' position involving an inspection system.

It is clear that programs are many and, viewed philosophically, it might well be said that we are currently engaged in trying to develop an atomic energy industry with none of the advantages of either the American or the Russian economic system.

Now let us return to the intriguing problem of picking the leading candidates for the next generation of reactors. We need reactors—more accurately, there is an expressed demand today for reactors—for the following purposes:

1. As a research tool, both by universities and by industry.
2. For mobile power, almost exclusively military.
3. For the production of fissionable material.
4. For the generation of power.

The first of these presents few problems since they can be in general, small, safe, and relatively inexpensive.

The second and third and fourth categories are already large, complex, and expensive, and for reasons given above, promise to remain so. And their development problems are inexorably interlocked. In order that advances in design in these enterprises can be made at lesser risk, we have found it necessary to establish still another category of reactors. This is really an interim class for developmental purposes, namely, the experimental test-prototype reactors.

These are reactors which will permit us to separate the variables inherent in the large multipurpose reactors. The EBR (experimental breeder reactor), for example, is one of these. As its name implies, it will enable the breeding problem to be studied essentially by itself with a minimum of interference from the demands of, let us say, high temperature, efficient production, or maximum power. A similar reactor which will permit us to test our knowledge, predictions, and techniques in connection with the homogeneous reactor approach has been authorized. Still another experimental reactor designed for the highest temperatures which could conceivably be obtained with "soon to become available" materials is on the drawing boards.

Beyond these a confusing array of still other reactors are being talked about. The problem is, and will continue to be, to select and focus major effort on those projects which promise the greatest long-range returns.

Summarizing then, and focusing our attention on trends, we note that discussion and interest has shifted from the question of whether power reactors can be built, to which should be built and which will prove most economical. This represents real technical progress. Current efforts are proceeding on two fronts, a direct attack on those problems confronting reactors for which there is a pres-

ent real demand, production, and mobile reactors, and a parallel attack on the applied research front, looking toward proved technological advances which at some future date can be safely incorporated in the main line of large reactors. We note a trend toward complex multipurpose reactors with civilian power probably emerging first as a by-product from production reactors and perhaps ultimately in its own right. Finally, we note an increasing interest on the part of the Commission to consider proposals for industrial participation.

All in all, though the road ahead is still long, I believe it would be safe for me to paraphrase the famous remark of General Collins on Korea, and say that "the beachhead of interest in civilian atomic power has been as small as it is ever going to get."

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5. REACTORS

By Lawrence R. Hafstad

(From the Scientific American, April 1951. Reprinted by permission)

Nuclear reactors are the machines for converting the energy of nuclear fission into forms that can be turned to useful purposes. They are large, complicated, expensive, and controversial. They provide man with the most concentrated energy source thus far devised, and in the imagination, at least, they have unlimited possibilities. The uses proposed for them have ranged from performance of the world's drudgery to the powering of rockets for space travel. Some of the proposed uses are strictly figments of the imagination. But reactors themselves, as a new type of machine with new potentialities, are a functioning reality, and it is now possible to discuss some of them publicly in considerable detail. Much of the information on the construction and performance of five early reactors, three of which are in the United States, has recently been declassified by agreement between the United States, Britain, and Canada.

This report will briefly describe the three declassified United States reactors and will survey the Atomic Energy Commission's general program of reactor development, with particular reference to new reactors of pioneering design now under development and construction.

Not the least striking feature of reactors is the great variety of possible designs. This is one of the things that makes them so vastly different from the power plants that we have been used to. Conventional coal burning furnaces, for example, are all generally recognizable as belonging to a common genus; they may differ in size and details, but essentially they are built and operated on the same fundamental plan. Imagine, however, a furnace variation which for fuel used carbon dioxide, say, instead of coal, which burned its fuel in a medium of water instead of air and which operated in a kettle instead of the usual firebox. That would certainly be a radical variation, but it is no more radical than the variations among the nuclear furnaces called reactors. The three reactors to be described here, all low-power machines used mainly for research, represent three very different types which indicate the wide range of possibilities.

THE GRAPHITE PILE

Let us take first the world's oldest nuclear reactor—the uranium-graphite pile at the University of Chicago in which a chain reaction was first achieved in 1942. This pile, later taken a part and rebuilt at the Argonne National Laboratory near Chicago, is a cube-shaped mass of blocks of graphite containing lumps of natural uranium or uranium oxide in a lattice arrangement; the oxide was used because only a small amount of pure uranium metal was available when the pile was built. The graphite blocks, which act as the moderator and the structural bricks of the pile, are 4⅛ inches square in cross section and of various lengths, usually 16½ inches. Some of the blocks have holes bored in them at intervals 8¼ inches apart. In these are inserted the uranium lumps, each a cylinder 2¼ inches in diameter and about 6 pounds in weight. The uranium-loaded blocks are called live. The solid graphite blocks without uranium are known as dead graphite; they are used for spacing and neutron-reflecting purposes. The pile was built up, layer by layer, with alternating layers of live and dead blocks. It became "critical"; i. e., started a self-sustaining chain reaction, when the fiftieth layer was laid on. Four layers of dead blocks were then laid on top as a reflector, and over this went a cover of 6 inches of lead and about 4 feet of wood.

The sides of the pile were surrounded with a similar reflecting barrier of at least 12 inches of dead graphite and with protective walls of concrete 5 feet thick.

When completed, the pile measured 30 feet wide, 32 feet long, and 21 feet high and had a total weight of more than 1,400 tons. It contained approximately 52 tons of uranium, in 3,200 lumps of the pure metal and 14,500 lumps of uranium oxide.

Openings were provided in the pile for five control rods 17 feet long. They are bronze strips covered with cadmium, an excellent absorber of neutrons. Three of the rods are automatic safety controls; they are equipped with 100-pound weights that quickly pull them into the pile in the event of electrical power failure or other emergency. The operating level, or power, of the pile is controlled by a single rod which is moved in or out to regulate the neutron flux. Because it lacks a cooling system, the maximum safe operating power of this pile is only 200 watts.

The research reactors at Oak Ridge and Brookhaven, and the great production piles at Hanford, are roughly similar to this first reactor. Their mass is largely graphite, and they are fueled by natural uranium. But they have systems for cooling, either by air or water, and therefore can run at higher power levels. They also have devices for loading and unloading fuel without tearing down the reactor. In addition they incorporate a number of other improvements and refinements required to provide dependable control for their much greater power and to serve their different purposes.

THE HEAVY-WATER TANK

The second type of reactor is the heavy-water unit at Argonne. This machine, whose dimensions have now been declassified, also was the first of its type in the world. It was built by the Manhattan district during the war because of the remote chance that graphite piles might not be able to produce fissionable material in the amounts needed for bombs. In this reactor heavy water, instead of graphite, is the moderator that slows fast neutrons emerging from the fission of U–235 atoms to the thermal speeds necessary for their capture by U–235 and the continuation of a chain reaction. In an aluminum tank 6 feet in diameter and about 9 feet high, filled with about 6½ tons of heavy water, are suspended 120 uranium metal rods 1.1 inches in diameter and 6 feet long. The rods are sheathed in aluminum for protection against corrosion. They are arranged to form a square lattice with 5⅝ inches between their centers. This reactor is smaller than the graphite pile because heavy water is more effective than graphite in slowing neutrons and does not absorb them as readily. Its total weight of uranium is less than 3 tons, in contrast to the 52 tons in the graphite pile.

The heavy-water reactor tank is surrounded on its bottom and sides by a 2-foot neutron reflector of graphite blocks. Around the reflector, in turn, are a 4-inch casing of lead-cadmium alloy and then a shield of concrete 8 feet thick. The reactor's top shielding consists of a layer of helium gas, a thin layer of cadmium metal, a 1-foot layer of lead bricks and finally a 4-foot layer of blocks of wood and steel.

Eleven small openings pierce the shield and reflector. These portholes, equipped with removable shielding plugs, are used to measure neutron intensity within the reactor, to insert materials for exposure to neutrons and to let beams of radiation emerge for experiments outside the reactor. There are also three large openings. One is a pocket roughly 30 inches square containing 20 hollow graphite receptacles in which materials can be placed for irradiation. Another is a graphite-plugged aperture 5 feet square which permits the passage from the reactor of a beam of slow neutrons. The third is a 4-inch aluminum pipe inserted in the tank through the top. Into this pipe, known as the central experimental thimble, samples of material may be lowered for exposure to the most intense radiations of both fast and slow neutrons. When all the reactor's openings are used, 32 irradiations can be performed simultaneously.

To cool the reactor, the heavy water circulates between the tank and an external heat exchanger at the rate of 200 gallons per minute. The cooling system is capable of handling 300 kilowatts of heat. Normally the heavy water is at a temperature of 95 degrees Fahrenheit when it emerges from the tank; after it has passed through the heat exchanger, it is about 7 or 8 degrees cooler.

The operator measures and controls all the major aspects of the reactor's operation at panels in a nearby room. To start the machine he pushes a button: this lifts the 32-pound safety rods out of the heavy water. Other buttons control two motor-driven rods that regulate the reactor power level. To shut off the reactor

the operator presses another button that causes the safety rods to fall back into the tank. If controls fail to function, if there is an interruption in the electricity supply or if for any reason the power level rises too high, the safety rods automatically fall into the "in" position by gravity. As further provision for an emergency shut-down there is a large quick-opening valve through which the heavy water can flow out into a storage tank. Without the moderator, the chain reaction promptly stops.

THE WATER BOILER

The third declassified reactor is the famous "water boiler" at Los Alamos. This is a homogeneous reactor, meaning that the fuel is distributed uniformly throughout the moderator instead of being in lumps or rods. The fuel, a uranyl salt, is dissolved in heavy water, and this solution, called soup by the reactor scientists, is both the fuel and the moderator. As a chain reaction develops, the solution heats up; hence the name water boiler.

The first version of this reactor was a low-power model known as LOPO. It had no shielding and reached a power of only a twentieth of a watt. In December 1944 LOPO was replaced by HYPO, a higher-powered model of 6 kilowatts which went critical with 1.8 pounds of U–235. Its fuel is enriched; that is, the uranium in the uranyl salt contains about one part of fissionable U–235 to six parts of U-238, instead of the 1-to-140 ratio in natural uranium.

The heart of this reactor is a 1-foot stainless-steel sphere filled with the "soup," a solution of uranyl nitrate. Then comes a reecting shell, or tamper, consisting of an inner layer of beryllium oxide and a thicker outer layer of graphite. Around this assembly is the shield: 4 inches of lead, one thirty-second inch of cadmium and 5 feet of poured concrete.

At the working face of the reactor a square tunnel pierces the shield. This tunnel is plugged with graphite to form a column for the passage of slow neutrons. The graphite column and the reflector have a number of ports for experimental irradiations. In addition there is a tube 1 inch in diameter that penetrates into the heart of the reactor itself. Through this tube, which Los Alamos workers call the glory hole, materials can be thrust into the sphere for exposure to a very high flux of neutrons.

The operation of HYPO presents some special problems. Cooling is accomplished easily enough by circulating water, at the rate of about 50 gallons per hour, through a coiled tube in the central sphere. But the highly ionized atoms produced by fissions in the reactor decompose the water in the fuel solution into an explosive mixture of hydrogen and oxygen gas, at the rate of about half a cubic foot of gas per hour. Moreover, the radiations also produce a small volume of highly radioactive gases. Consequently the design has to provide a means for constantly diluting and flushing out these gases.

Under normal operating conditions the water boiler has a natural self-regulating action that prevents it from getting out of control. As the reaction rate and the temperature rise, the solution expands in volume, the U–235 atoms move farther apart and the reactivity per unit volume therefore declines. This automatically slows down the reaction and holds it within safe limits. HYPO has a safety control rod, nonetheless, and two regulating rods for accurate control of its flux. Since extremely accurate regulation requires almost continuous adjustment of the control rods and this can become tedious over long periods, the reactor has been provided with an automatic pilot that can hold the power at any desired level with an accuracy within a few tenths of 1 percent. An experienced operator can bring HYPO up to full power in a few seconds. If cooled by water at about 45° F., HYPO can run continuously at 5.5 kilowatts without exceeding a solution temperature of 185° F.

HYPO is the smallest and most economical type of chain reactor. It has been used primarily for research experiments requiring a concentrated neutron source. The research reactor which the Consolidated University of North Carolina plans to build at North Carolina State College will be of this type.

THE NEW GENERATION

So much for the description of the declassified reactors. Publication of the details may help citizens to begin to feel at home with these new machines of our civilization. But it must be remembered that the units described here were among the first built. By now they represent mere taking-off points for the better reactors that have been built since and for further improved ones that are under construction or envisioned for the future. The program for developing

better reactors still faces many unsolved technical problems. We need materials that will stand very high temperatures and intense radiations and that will not absorb too many neutrons; we need more efficient shielding and control gear with very rapid response times; we need ways of attaining heat-transfer rates higher by an order of magnitude than those conventionally used in power plants; we need better ways of handling fission products in the reactor and of disposing of radioactive wastes. The national laboratories of the Atomic Energy Commission have been occupied with these problems since 1945. Much progress has been made toward solutions, but just how much is difficult to assess without some full-scale trials. During the coming year some of these trials will begin, as several reactors of new and advanced design come into operation.

The AEC has five major reactor projects under way. First there is the experimental breeder reactor, designed primarily to explore the possibilities of breeding; that is, producing more fissionable material than is consumed. This reactor will operate in the fast-neutron energy range. Construction and fabrication are practically complete and installation is beginning. The second is the materials-testing reactor, designed for the highest neutron flux yet attempted. As its name indicates, it will be used in the development of other reactors. Construction is well advanced. Third, there is the slow-neutron ship-propulsion reactor, a land-based prototype of a reactor for propelling submarines. Construction is under way. Fourth is the ship-propulsion reactor designed to operate in the intermediate-neutron energy range, in which we have had no experience. This project replaces an earlier project for an intermediate reactor for both power and breeding. It is in an early stage of development and design. And fifth, there is a homogeneous reactor, of moderate size, which will serve as a pilot model to spearhead further exploration of reactor designs of this type. It is under construction.

Now that actual construction of most of these reactors has started, we are acquiring, for the first time since 1942, an objective measure of the state of the art in reactor technology. We can see that the laboratories have done an adequate job of applied research and have provided the engineering designers with adequate handbook data. The designers in turn seem to have avoided gross miscalculations, at least as far as the early construction has gone. But final answers must wait until the present generation of reactors has been carried through the debugging stage and is in actual operation.

THE NEXT GENERATION

Already, as is not surprising, there is considerable discussion of the next generation of reactors. What types should be chosen for trial? There are all sorts of possibilities. With breeders and nonbreeders; high, low, and intermediate neutron energy; high, low, and medium temperatures; natural, slightly enriched, and highly enriched fuels; homogeneous and heterogeneous fuel distributions; assorted moderators, coolants, and corrosion-resisting coatings—with all these possible variations the number of permutations and combinations runs high. The problem is not to invent a reactor; the problem is to select one that will yield maximum returns. Remember that reactors are expensive. Small ones cost from $1 million to $5 million; large ones $25 million to $50 million or more.

We must start by considering what our reactor needs are. We know that we need reactors for producing fissionable material for military use if for no other. We believe we can probably use to advantage mobile power reactors for propulsion, if the cost in both dollars and fissionable material does not prove to be prohibitive. On the other hand it is clear that we can justify heavy commitments to reactors for industrial electric power only if and when the cost of this power bears a reasonable relationship to the cost under comparable conditions of power available from conventional fuels. These are the boundary conditions.

Unfortunately, to assess the need for a given type of reactor we must know the cost, but costs, in turn, can only be determined by first building reactors. This is the circular argument in which we continually find ourselves. To break out of this vicious circle we use the fact that for the military needs the unknown economic factor is less compelling than it is for civilian needs.

A few other genreal conclusions can be drawn from experience. For example, with fissionable material in great demand for bombs, it is logical to concentrate on those types of power reactors that will at least partially replenish the fissionable fuel used up. Therefore we think of mobile military reactors which would produce plutonium as well as power. Eventually these reactors should

breed, that is, manufacture more fissionable material than they consume. For civilian purposes also we should prefer reactors that produce fissionable material along with power, since breeding would reduce the cost of such power. Thus the difficulties are not separable into neat little problems which can be solved one at a time by themselves; the trend rather appears to be toward greater complexity with a pronounced interlock between fuel-producing mobile-military, and civilian power reactors.

The economic factor insistently intrudes itself into what we would like to consider a purely technical problem. Critics of the United States atomic energy program assume that civilian atomic power could be made cheap and generally available if only those in authority had the will to do it. The assumption is that by another billion-dollar crash program like that of the Manhattan District the remaining necessary secrets could be uncovered and the real atomic era ushered in. Actually the atomic bomb problem and the civilian power problem have little in common except the language. They differ in kind rather than in degree.

The bomb project was almost uniquely black and white: it was either a grand success or a colossal failure. The civilian power problem is quite different. Enough technical facts have long been known to assure us that electric power can be produced—if we are willing to pay the price. There is an analogy in the proposition of producing electric power from the winds or the tides. Our technical ability to tap these sources of energy is not questioned. But we don't utilize the wind and the tide because the power so produced would be more costly than that obtained conventionally from coal and oil.

The cost of construction of a nuclear power plant is still essentially unknown. We have never even designed, much less built and operated, a reactor intended to deliver significant amounts of power economically. Our experience is that in this business estimates cannot be taken at face value and invariably turn out to be too low. My own approach has been to try to find the upper limit for the cost of a power plant, basing this estimate on the firmest available figures on the most nearly similar reactor either already built or under construction. Estimates based on the cost of low-temperature reactors for producing plutonium, on the assumption that they can be redesigned for operation at higher temperatures, cannot be taken seriously.

YARDSTICK

We are driven back to the slow-neutron ship-propulsion reactor now under construction as the best yardstick for the probable cost of a nuclear power plant. The cost of this mobile reactor has been estimated roughly as $1,400 per kilowatt-hour of installed electrical capacity. The corresponding cost of a conventional stationary coal-burning power plant is $100 to $150 per kilowatt-hour capacity. Now we know that many savings can be made in the $1,400 figure for the mobile nuclear plant. In a plant for civilian power it seems possible that we could avoid some of the high costs involved in developing a prototype reactor, in meeting the Navy's requirements of weight and space, in reprocessing fuels, in the lack of volume production, in the extreme military security precautions and in the extreme precautions for safety of personnel. If we could pick up a factor of two or three through savings in these items and through the technical improvements that will almost certainly come in a field as new as atomic energy, we would begin to close in on the competitive figure of $100 to $150.

The fuel costs are not negligible and are even more uncertain than construction costs. All fissionable material thus far manufactured has been produced by a Government monopoly on a high-pressure basis in such a way that precise cost allocations simply cannot be made. Taking from the open literature the figure of $20 per gram for nuclear fuel, we get a fuel cost of one mill per kilowatt-hour, as compared with two mills for coal. The $20 figure is almost certainly low, and it seems likely that it will rise as the supply of high-grade uranium ore runs out. Hence it appears that fuel costs will be about the same for a power plant burning U–235 as for one burning coal, while the cost of the installation, and probably of its operation, will be considerably higher.

The civilian power plant need not, however, confine itself to producing power: it could also produce plutonium. The reactors now producing plutonium throw away their heat—hundreds of thousands of kilowatts of it. Suppose this heat could be put to some useful purpose, say the production of power, or even the distillation of sea water? What then is the economic picture?

Technically a reactor to produce both power and plutonium is not out of the realm of possibility, but scientists don't know much about such a reactor yet. If

one can be made to work, much of the operating cost will be charged off to the production of the fuel, and the power may be provided at reasonable cost.

ENTER PRIVATE COMPETITION

It is my opinion that the fastest progress toward settlement of these issues will be made if we move toward the design, construction and operation of reactors on a competitive-bid, fixed-price basis, or otherwise utilize the profit incentive. Because of security and safety problems it will not be easy, but I believe that it can be done, if industrial people with the know-how and we in Washington have the will and the ingenuity.

Progress in the atomic energy field has brought both Government and industry to a point where each can see fairly clearly the real nature of the joint Government-industry effort that is required. In some respects only the problems to be solved are clear, but the problems have been identified sufficiently for both the Commission and industry to determine the most effective role each must play. Over the past few years the level of the Government's reservoir of technical knowledge has been substantially raised. In the meantime industry has expanded its competence in the field of atomic energy and begun to see its own role in terms of something more than job contracts.

During recent months the Atomic Energy Commission has received proposals from two industrial groups expressing willingness to bring their technical resources into the atomic energy program on a basis of new and greater responsibility. One proposal is from a group interested in the possibility of building reactors with its own capital and operating them to manufacture plutonium to sell to the AEC and electric power to sell to the industrial market. The other proposal is similar, though concerned principally with initial investigations. The Commission has replied that it welcomes these proposals and is ready to discuss arrangements for the first step, which would be a study to the state of reactor technology by representatives of the interested firms.

THE ROCKY ROAD AHEAD

Suppose now that either out of AEC laboratories or from industrial contractors there emerges a design of a reactor producing plutonium and yielding electric power as a byproduct. Will this finally usher in the atomic era? I am afraid not. The major charges will still be carried by the military need for plutonium. Only if and when civilian power can pay its own way, from the uranium mines to the waste-disposal dump, can it truly be said that the civilian atomic power problem will have been solved. In the meantime we would be less than prudent if we did not take advantage of every opportunity to make the operation of reactors economically practical by increasing emphasis on the use of byproducts, whether military or civilian.

Assuming that it is desirable to have greater industrial participation—and by this is meant responsible, cost-reducing, competitive participation—we must anticipate certain serious problems. First and foremost will be the problem of shortage of personnel. A recent examination of the national scientific roster turned up a total of only 350 names of persons who list themselves as mathematical or nuclear physicists. Of these most are engaged in university teaching. So it is not surprising that we count our experienced reactor designers almost on our fingers, and these are committed and overcommitted by the present program. Nothing would cause more disruption than an irresponsible, uncontrolled proselyting of keymen. The solution lies in a training program on an expanded scale.

A second very serious problem will be that of unpredictable costs which may be introduced by Government decree. These will be mainly in the fields of security, accounting for fissionable material and safety. A third problem is that the Government is reluctant to commit itself to long-term expenditures; yet in a development as ponderous as that of atomic energy any privately financed industrial approach would have to be based on firm plans for 5, 10, or more years.

Another knotty problem is the question of how to distribute the opportunity to play an active part in this field fairly among the many interested parties. One is reminded of the early days of radio when lawyers argued furiously that each citizen, or group of citizens, had a constitutional right to an equal share of the radio-frequency spectrum. The fact that the extent of the available spectrum was limited by natural law somehow did not seem to register.

Finally, there is the category of legal problems, some of which will require congressional action. Additional complications may arise from developments in the United Nations concerning an international inspection system for atomic energy.

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6. THE ATOMIC ENERGY COMMISSION REACTOR PROGRAM

Remarks Before the Oak Ridge Summer Symposium, Oak Ridge, Tenn., September 5, 1951

I should like to make some remarks about the Commission's reactor development program—past, present, and future. The look to the future will lead us into a very brief examination of the world's fuel resources and the possible place of uranium among them. Then, in closing, I believe you will be interested in the security problem which is, of course, closely related to the cold war and Russia's attitude to science.

Let us begin with the postwar period of uncertainty in the atomic energy field. In the midst of the dark clouds of late 1945 and 1946, there was faith—faith by a few scientists and engineers scattered around the country that the business of atomic energy, as it is manifest in reactors, would somehow or other find practical use. The reactor program is due in large part to these scientists who kept struggling with reactors during the low period immediately after the war.

There were many complications at that time. Part of them, I think we have to accept frankly, were troubles created by the scientists themselves. My impression is that the young scientists were particularly concerned at the end of the war to get out from under military control and that their concern led them to talk a little too glibly of the ultimate promise of atomic energy. This was the period of prediction of boundless, cheap electrical energy at the expense of the atom.

Then the pendulum began to swing the other way. More conservative people started pointing out how difficult it would be to get energy out of the atom. This led many to believe that there wasn't much future in the reactor program.

A number of things happened to clear the waters. One was the emergence of the military interest in mobile reactors. The military requirement could be used to develop a reactor technology. So this was one line of advance we were able to follow. Another spur to the program came from the realization that the Nation's difference with the Communists was going to be of long standing, that we would have to go on making atom bombs. This at least meant interest in reactors for the production of fissionable material.

But we already had production reactors at Hanford. There would have been no interest in reactors of new design without another element in the picture. This was gradual improvement in the supply of raw materials. The reactor scientists and engineers who operated essentially on faith in the early days more or less took it for granted that the uranium supply would follow the pattern of other natural resources. For the past several decades, prediction after prediction has had the country running out of petroleum, yet we have petroleum for more automobiles than ever before. It was considered likely that the same thing would happen with uranium, that as the needs develop and as exploration for the mineral expands, more and more uranium would become available.

WHY BUILD REACTORS

Now let us return to the basic question: "Why should we build reactors?" There are two reasons. One is power, central station power for the country's electric distribution system. You can really get enormous amounts of power from very small amounts of fissionable material. The figure I carry in mind is a convenient one for the layman. There is the same amount of power in one pound of fissionable material as in 2,600,000 pounds of coal. This comparison indicates the concentration of power we are dealing with.

Now, the fact that you can get the power is not the whole story, as has already been implied. The important question is: "How much does the power cost?" If power from this source is more expensive than that from coal and other conventional fuels, the country certainly is not going to build nuclear plants to produce civilian electric power. However, our power supply is not unlimited. Later in this article I shall report estimates of available reserves of conventional fuels and compare them with estimated reserves of atomic fuels.

The other reason for building reactors is the military reason. As we have seen, there are two kinds of military reactors—production reactors for producing bomb materials and mobile reactors.

In brief, these are the needs and the reasons we are in the reactor business. Now, how do you lay out a reactor program?

THE BASIC REACTOR PROGRAM

As is generally known, there are an enormous number of possible reactor designs. There are so many designs that one cannot expect to get enough money from the United States Government to exploit all. Hence, sooner or later the people in charge of the over-all program have to sit down and decide which of these various reactor designs are going to be backed. This is a phase that we go through at intervals.

The first group of reactors backed consisted of the experimental breeder reactor, the materials testing reactor, the intermediate power-breeder reactor, and the submarine thermal reactor. These were the four which looked like they would give a reasonably balanced program, would contribute to the immediate needs of military mobile reactors, would contribute to the ultimate needs of the production of fissionable materials, especially through breeders, and would promise to give an appreciable amount of civilian power at some time in the distant future. This distant promise of civilian power was the main reason for the power-breeder.

Those who are closely connected with these technical developments will agree, I am sure, that once such a decision has been made, it is very important to stand behind it so that the job undertaken can be finished. This is necessary to keep stability in the program. If we continually change our minds, there will be trouble. Our sights have been held on these reactors, and three of them are coming through exactly as planned. Research and development for the fourth, the intermediate power-breeder, suffered a deviation. The goal was shifted and made a submarine power reactor in the intermediate energy range. This is an example of shifting from long-term to short-term objectives, from general to specific assignments. This sort of thing becomes necessary from time to time in order to tighten up the program. These four reactors are now coming through and should be showing what they are good for during the next year or two. These reactors constitute the basic part of the AEC's reactor development program.

THE PRESENT INTERIM PROGRAM

At the present time, I would say that the AEC has an interim reactor development program. We are again in the stage of talking about a large number of different reactors. This is healthy because as many different bright ideas as we can get are needed. A number of these ideas are being backed on a relatively moderate scale.

For general thinking, it can be assumed that the development and construction of a major reactor costs something like $25 million; a big reactor, $50 million or more. A small experimental reactor costs in the neighborhood of $1 to $5 million. Some of the better bright ideas that have turned up in the last few years are now in the form of small experimental reactors. Within the next year, I think we shall have to decide what the big reactors are going to be in the next chapter of the reactor program. In summary, a lot of paper studies are being conducted at the present time, a considerable amout of experimental work backing up these paper studies is going on, and we are beginning to build exploratory experimental reactors, such as the homogeneous reactor experiment.

THE FUTURE PROGRAM

As to the trend for the future, I should like to call attention to three basic groups of reactor designs which show particular promise for different reasons.

There is enthusiasm about the homogeneous reactor approach. In this type of reactor, instead of very carefully machined fuel elements made of very unusual materials—an extremely expensive procedure—the reacting parts will consist of a solution, or a slurry or mixture of very fine particles. This is why it is called homogeneous. This solution, or slurry, can be pumped through a tank in which the nuclear reaction takes place and then pumped out again—hot in two senses, temperature and radioactivity. The heat at high temperature can be used through a heat transfer mechanism to provide steam, or in some other conventional way be converted into mechanical or electrical energy.

The great virtues of the homogeneous design are that it avoids the complicated mechanical design of the heterogeneous type of reactor and should simplify the fuel reprocessing problem. The difficulties of fuel reprocessing are ever present. After a reactor has run for a while, there is an accumulation of fission products. These fission products are analagous to ashes from the burning of coal. When too many fission products accumulate, the reaction stops just as a coal fire goes out when too many ashes and clinkers clog the fire bed. It is necessary to provide a mechanism for removing the fission products, and apparently this can be more readily done for homogeneous fuel.

The second promising type of reactor design is the breeder reactor. I will try to explain how breeding works. My scientict friends doubtless will say that I oversimplify; but that will be justified if the lay members of the audience improve their understanding of the breeder thereby.

It happens that uranium, as it is found in nature, comes in two forms—two isotopes, we call them. They are uranium 235 which is fissionable and uranium 238 which is not fissionable and therefore useless as far as reactors and atomic energy are concerned. Unfortunately, the fissionable kind of uranium, the U–235, is only seven-tenths of 1 percent of the total supply of mineral uranium in the earth. In other words, there is about 140 times as much useless material as there is useful material.

The intriguing possibility exists theoretically that a reactor might be made to create more fissionable material than it consumes. Roughly, here is the way it would work. It happens that when the fission process is going on in a reactor a few extra neutrons come out of each fission so that, on the average three neutrons, we will say, come from the disintegration of each fissionable atom. One of these three neutrons goes to keep the chain reaction going, to cause another fuel atom to fission. Another neutron is required to convert one uranium 238 atom into a fissionable form of atom which, in this case, would be plutonium. One neutron is left over. Actually, only a fraction of a neutron remains, but to make the arithmetic easy, we will say that one neutron is left over. This neutron could be used to produce one more fissionable atom from another atom of U–238. If this were done after each fission process, the atom lost originally would be replaced and one additional fissionable atom would be created. In other words, as the reaction proceeds more fissionable material would be produced than consumed.

This sounds so much like perpetual motion that I hasten to add that the process can go on only as long as there is an amount of U–238 at hand. As an analogy, let me compare uranium with skim milk and cream. A reactor runs only on the cream. The skim milk, the U–238, is useless. In a breeder reactor, however, we can convert gradually part of the skim milk, the U–238, into cream, into a fissionable form, plutonium. Now this is well worth doing, because if we succeed we will increase the potentially available fissionable material by a factor which is a substantial part of 140. There is much excitement when a new oil field is discovered which increases the available oil supply by perhaps 10 percent. Here we are on the verge of a discovery which may increase the uranium supply several thousand percent. This is really an exciting possibility and one which we will exploit to the fullest.

It may not work. There are many difficulties in it which you people ought to be aware of. For example, the materials a reactor is made of absorb neutrons, steal them from the chain reaction. It is necessary to develop materials with sufficiently low absorption. Here is another difficulty. There must be an excess of plutonium converted from U–238 not just after use of fuel one time in the reactor but also after chemical processing and fabrication of the fuel. The excess from the reactor must be more than enough to cover losses in processing and fabrication. Of course, the losses have to be kept to a minimum.

This sketching of possibilities along with problems is enough to indicate why the breeder reactor approach is particularly interesting. A breeder may be either a heterogeneous or a homogeneous reactor. The breeding process will work for either thorium or uranium. In the case of thorium, breeding will convert unfissionable thorium into fissionable U–233.[1] As you see, breeding is a very versatile possibility.

A beginning has been made into these investigations with the experimental breeder reactor, assembly of which was completed during the summer at the reactor testing station in Idaho and which is now being given preliminary testing.

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[1] Uranium 233 is one of the three known fissionable materials, the other two being uranium 235 and plutonium 239.

However, it may be many months before we get an indication of breeding performance from this reactor.

The third promising reactor design is that providing for a very high burn-up of fuel for each loading of fuel elements. The difficulties connected with chemical processing can be minimized by having the processing occur as infrequently as possible. If the reactor, complicated though it be, uses one change of fuel over a very long period of time, perhaps converting U–238 into fissionable material and gradually burning up the U–238 and the plutonium produced from it along with the original U–235, then high burn-ups become possibble, and considerable reprocessing cost and loss can be saved. This is another approach which has long-term possibilities and one we shall exploit to the extent the technology permits.

These are the main avenues of advance in the reactor art. Since they are capable of delivering both power or fissionable material, they could contribute to both of our military demands. They would give us fissionable material for the bomb supply and fissionable material which could be converted to mechanical energy to propel ships or aircraft.

SWORDS INTO PLOWSHARES

There is a technical "break" in this situation which is a great advantage to all of us. It is the fact that the technology developed in connection with military mobile reactors will be useful in providing civilian atomic energy and, conversely, that any stockpile of fissionable material the military builds up for atom bombs or mobile reactors, if not used, will ultimately be available for conversion into civilian atomic energy.

This is a fortunate natural event. Just the opposite is true in the case of TNT. The military needs enormous quantities of TNT and other chemical explosives, and go into production on an enormous scale during war. At the end of the war we have a big disposal problem to burn up and blow up the accumulated supply. On the other hand, if we stockpile atom bombs, when peace comes we can always use the fissionable material of the bombs to produce electrical energy.

There are big dividends, then, to be gotten from this military interest in reactors. As for the past, I think that the only way we could have made progress with the reactor program was to take advantage of the military interest. This we have done vigorously, and I hope the next few months, or the next year or two, will indicate that we have done it successfully.

There is a negative factor which should be mentioned at this point. It is the problem of security, the difficulties introduced by security measures into the carrying out of a military research and development program. This problem will be discussed later.

POSSIBILITIES FOR EXPANSION

If current reactor developments turn out successfully and costs can be further reduced, the demands for reactors will increase indefinitely, I believe. Let us follow one avenue with unclassified information. We have read in the newspapers about the big atom bombs used in strategic bombing, and we have gotten hints from the papers about the use in artillery pieces of smaller, tactical atom bombs. Most of us know enough about military operations to realize that when the field artillery starts using a particular kind of ammunition, a production problem is created. I don't know of any organization that can burn up expensive equipment faster than a field artillery division, and if they start popping atom bombs around—even small bombs—we are going to have really enormous requirements for the bombs. It seems to me that there will be a continuing market for fissionable material for bombs for tactical uses, whether for artillery or small airplanes.

As soon as some experience is acquired with the naval reactor, we may face an appreciable conversion of naval propulsion equipment to atomic power. The demand will certainly be there if the device is successful. The extent to which the Navy converts will depend only on the Nation's success in providing for the supply of fissionable material. This means either we have to find new sources of raw materials or we have to get busy and make breeding work in order to provide the needed nuclear fuel. These trends and possibilities indicate that there will be an increasing military demand for fissionable material over the next decade or so, at least until our present difference with Russia is clarified. To help meet this demand, the reactor business is likely to flourish for the foreseeable future.

But even the military will not furnish the big demand which I think will carry the reactor business over a long period of time. Civilian interest will be almost entirely in electrical power, in the conversion of fissionable material into plain, ordinary electricity. As has been pointed out, reactor costs are high at present, and nuclear electrical power is uneconomical. However, a start into the civilian power field may be possible by use of byproduct electric power with military requirements for fissionable material carrying most of the cost of the development and construction of reactors.

Fissionable material producing reactors release large amounts of heat which can be converted into civilian electric power. A reactor for the dual purpose will cost more than a reactor for turning out fissionable material only, but probably not too much more. Also, it appears that operating costs may not be very much larger. In the first dual-purpose reactor we would strive for costs not to exceed the present cost of fissionable material to AEC plus a power cost that would make the byproduct nuclear power competitive with power from coal, oil, or hydro plants.

Long-range trends seem to favor nuclear central station power. In a new technology costs are constantly going down. Meanwhile, the cost of power from competitive sources is going up. Oil is becoming increasingly more scarce and the cost of coal is continually increasing, due to both increasing costs of mining and increasing scarcity. In due course, we may reach the stage where some civilian nuclear power can be produced first as a byproduct and ultimately as the primary product competing with coal and oil. Even if direct competition is not reached, it may be that there will be a reactor industry anyway just for its peculiar advantages such as the quick conversion of the fuel from civilian into military potential.

A path of this kind is not new. From the hard headed dollars-and-cents point of view, it probably can be shown that most airlines are uneconomical. But the planes fly every day. Now the reason that they fly is that there is a national need for an aviation industry. With the help of subsidies which include air mail, navigational aids, and airports, there is a vigorous civilian air transport industry, even though it might be called uneconomical. The railroads were subsidized in their early days and in a sense the automobile industry is subsidized now by highway building. Something similar may emerge in the case of nuclear power. It may be that Government interests will be sufficient to subsidize a civilian nuclear power industry.

So much for the ways in which reactors may develop, as best we can see them at the present time. Now, what is known about the demand for energy?

Some good studies on the national demand for energy are being made, although prediction in this field is still much a matter of crystal gazing. Of course, this country is not going to feed electricty from nuclear energy into its transmission networks so long as there are ample supplies of cheaper sources of energy available. However, studies are being made which indicate that energy sources are not unlimited.

GLEESON'S 12 POINTS

I would like to read conclusions from a recent paper by G. W. Gleeson, dean of engineering at Oregon State College. In a discussion of the subject, Energy—Choose It Wisely Today for Safety Tomorrow,[2] Dean Gleeson comes to the 12 conclusions listed below. The parentheses enclose my own comments.

1. That, with the exception of hydroelectric power, our energy comes from discontinuous sources, the fuels of which are finite in amount.

2. That our economy is expanding in proportion to our energy use, and we can expect greater demands upon our energy sources.

3. That, while there are ample and available sources of energy to provide for our immediate requirements, and while such sources can be expanded to an appreciable degree, they are, nevertheless, finite.

4. That, in the interest of future generations as well as in the interest of true conservation, we should hoard our fossil fuels wherever possible, particularly petroleum. (I would like to digress here and say that I hope, sooner or later, our country will be in the position of declaring that for stationary power plants and large blocks of power, we cannot afford to use petroleum. U–238 ought to be good enough.)

5. That, to conserve our fossil fuels infers substitutions of one discontinuous source for another and continuous sources for the discontinuous

[2] Published in American Society of Heating and Ventilating Engineers Journal Section, Heating, Piping and Air Conditioning, August 1951.

sources. (Continuous sources are those which take energy directly from the sun.)

6. That there are distinct possibilities of greater development and use of continuous sources of energy which Ayers[3] has estimated to be probable within 100 years. (This shows the time scale we are up against as far as coal and oil are concerned. According to this study, we will have to start moving toward solar energy within 100 years.)

7. That energy sources, limitations, and locations may well influence our living patterns through change in architectural design, industrial locations, comparative prices of fuels, and the development of more integrated energy systems.

8. That, in addition to the development of new sources of energy, we have much to accomplish by way of improvement in the use of currently developed sources through higher efficiencies of utilization, transport, and conversion.

9. That periodic inventory of power energy resources is just as important as for other natural resources.

10. That we should be willing to pay a premium now in terms of research and development to effect conservation of our least adequate in amount, but most useful in form, sources of energy. Such research as shale oil recovery, liquid fuels from coal, utilization of vegetable waste, etc., should continue to receive adequate public support.

To this tenth point I would add "ditto" for atomic energy. Dr. Gleeson's study does not emphasize atomic energy probably for the obvious reason that little information can be made available for general study. But it seems to me that these remarks apply as much to energy from nuclear as from other sources. Liquid fuels from coal, although attractive on the surface, probably are not a good ultimate solution for the simple reason that half of the available energy of the coal is lost in the conversion. This is a high price to pay for convenience.

11. That we should direct conservation effort preferentially to areas of largest consumption such as space heating and provision of process heat.

12. That, in the public interest, we should eliminate wasteful processes where conservation could be effected by substitution, even if such substitution results in a temporary economic disadvantage.

FUEL BURN-UP AND RESERVES

I have read these conclusions to emphasize the fact that we are approaching the stage where we have to begin to think about our available reserves of energy. Those of you who have been reading in this field probably find, as I do, that the mind rebels at the tremendously long numbers one has to deal with—millions and billions and trillions of B. t. u., for example. We in the Atomic Energy Commission recently had a study made in this field by Palmer Putnam, a consulting engineer. I find his summaries very helpful. He probably oversimplifies, but this helps. It enables me to get a grasp of the numbers involved.

Mr. Putnam introduces a new symbol Q, which keeps the numbers small. One Q equals 1×10^{18} B. t. u. (British thermal units). Ten to the eighteenth power (10^{18}) is a million million million, a pretty good-sized figure. The advantage of Q is that a person can begin to think of the quantities of energy consumed in convenient small numbers. For example, during the year 1947 the world burn-up of energy was about 0.1 of a Q.

It is estimated that the world burn-up from the year 1 A. D. all the way to 1860 was between 6 and 9 Q. It is interesting that in all that time, nearly 2,000 years, the people of the earth burned up less than 9 Q, whereas in just one recent year, 1947, they burned up some 0.1 of a Q.

Energy demands are going up rapidly. For the period 1860 to 1947, the burn-up was 4 Q. It is estimated that in the period of 1950-2000 we may burn up energy at the rate of 40 Q per century. Beyond 2000 A. D., if population and energy demands continue to increase as seems plausible, the inhabitants of the earth will be burning energy at the rate of 100 Q a century. Perhaps I should say we may be demanding energy at the rate of 100 Q. Remember these numbers. They range from 1 to 100 Q.

Now, let us take a look at our reserves. The United States Geological Survey says that the total available coal reserves contain 68 Q. That is not a large number compared to the 100 Q per century it looks like we will be demanding

[3] Major Sources of Energy, by E. Ayres (28th annual meeting of the API, Chicago, Ill., November 9, 1948).

beyond the year 2000. But there is worse news. The 68 Q represents the energy in all the coal available, according to the geologists. The Bureau of Mines says that the economically recoverable coal contains only about 6 Q, which is pretty small compared to the 100 Q. The economically recoverable oil and gas would supply only 0.4 of a Q. There is likely to be trouble ahead, if these estimates are correct.

Faced with such pessimistic estimates, one is prompted to ask "Can atomic energy help?" Well, it is anybody's guess as to what the exact figures for atomic energy are, and I do not want anyone to take too seriously the figure I shall give. We simply do not know what the reserves of uranium are and we do not know how far down toward the lower grade ores it is economical to recover uranium. However, it can be said that the shorter the supply of coal, oil, and gas becomes, the more dividends we will collect from a breeder reactor, if it can be made to work. Assuming that the breeder process works and that all available uranium can be used, Putnam's study comes up with a guess—and he does not claim it to be any more than a guess—of at least 100 Q for the economically recoverable reserves of uranium. This would last the world many decades and would probably give time to develop the art of using continuous solar energy, as Conant has recently pointed out we must ultimately learn to do.

THE SECURITY PROBLEM

Thus far we have taken a quick look at the technical problems connected with reactor development and at the directions of promise and the demands. Now I would like to talk about the security problem. This is an important subject just now because groups like yours coming into an atomic-energy laboratory and bedeviled with our security restrictions nearly always feel resentment against this security. There may also be a building up of concern against the military emphasis and against the reasons for the military reactor projects. I would like to examine some of these points with you.

The most attractive solution to the security problem would be to declare that we are at peace—at least not at war—and therefore relax restrictions and make as much technical progress as possible by virtue of the increased freedom of action. If and when a war threat appears, we would be in a strong position to convert the civilian to military potential and defend ourselves as necessary.

Of course, the security problem is not so simple. At least it is not so simple according to the thinking I have done on this subject, and I have tried to follow it pretty carefully because security is a real headache to the reactor program. I think most of us agree that our country is in a cold war and that it is a situation which is certainly different from true peace and which we find both uncomfortable and confusing. It is a peculiar situation, we do not quite know in what direction to move. As I see it, we are forced to conclude that, although we are not in a shooting war with Russia, that country—at least its Communist leaders—seem to be at war with us in the field of ethics and ideas. If you look at the situation this way, then you have to accept all the security requirements and restrictions that go along with it. Let us prod into relations between the two countries in the field of scientific information.

SCIENTIFIC INFORMATION, RUSSIA AND THE FREE WORLD

I make the statement that, especially in the atomic energy field, I think Russia is at war with us. Now, what is the evidence? Well, in this country we believe in free speech, free exchange of scientific information, freedom of political debate and other freedoms such as freedom of work, which excludes regimentation of labor. The Communists in general prostitute these freedoms, while those in our midst take advantage of them. Indeed the very fact that we are open and free gives them a one-sided advantage in acquiring all the information we give out. Hence, to protect ourselves, we have to devise some kind of security requirements, onerous though they may be.

The situation is a peculiar one. The Communists have a program; we have ideals. They are aggressive; we are defensive. They happen to be in the position of taking the initiative; we have not yet taken the offensive. We, as a democracy, are preoccupied with threats to our freedom and so many other things that we are unbalanced, which makes it extremely difficult to defend ourselves and take prompt countermeasures against aggression.

As an analogy, I think we are roughly in the position of a host who has a weekend open house and finds himself saddled with an obnoxious guest who takes

advantage of the privileges. The host does not know quite what to do with such a guest. He is not quite ready to call the police to throw the man out, because he does not want to ruin the party for the rest of his guests. So instead of taking action he merely hopes that the trouble will subside. I think that is about the situation we are in, vis-à-vis the Communists.

There are many reasons why we, as physical scientists, far from being predisposed to take to the party line should be particularly concerned about the Communist threat. I will mention a few of these reasons and hope to stimulate you to explore these things further. The main reason for concern is that the Communists' philosophy is diametrically opposed not only to the modern theories of physical science but even to the very "scientific method" as we practice it in our day-to-day work to advance the theories.

I did not realize this until recently. I had read in newspapers about the controversy in biology and the Lysenko argument. Some of you must have kept up with this. I urge you to read further and I recommend highly a book called The Death of a Science in Russia, written by Zirkel, which describes in documented detail the attack by the Russian Communists on biology and genetics as the free world knows these sciences. This attack is extremely significant because they show that the Russian social philosophy simply cannot tolerate free science. The history of genetics and geneticists in Russia gives an indication of the little freedom of science the rulers of the country permit.

Though without corresponding publicity, physical science there is going through exactly the same sort of attack. Documents are available which indicate that the Communist dogma cannot accept such things as the uncertainty principle. Einstein's theory and quantum mechanics. These are unmechanistic. Because they are unmechanistic, they are unreal and idealistic, according to the Russian politicians. Their social philosophy based on the physics of 1890 cannot tolerate this modern kind of physics. The Communists' demonstrated policies of political domination and control of scientific theories are a threat to us all as working scientists, Russian as well as free. The situation is also an opportunity, because we can speak up as scientists and defend the truth as we see it; and the more we defend free science, the more we embarrass the Politburo. I urge you to explore this field.

There are other quarrels which we as scientists have with the Communist philosophy. I will not dwell on the way in which they used our ex-colleagues—May, Fuchs, and Pontecorvo. This is a well-known story. However, for a good, balanced discussion of the pros and cons of the security problem I recommend The Battle Against Disloyalty by Nathaniel Weyl. It will make you much more tolerant of the security difficulties in which we find ourselves.

AN EXAMPLE OF PROPAGANDA

A little personal experience in connection with the way the Russians operate might be instructive as well as amusing. Friends called to my attention an article in the Daily Worker which referred to a fellow by the name of Hafstad as a "learned bandit." Naturally, I was both flattered and curious, and so we located the document on which the article was based. It was an article by a Russian named Golubtsov who wrote in the Russian Literary Gazette, published in Moscow. In due course, I managed to get a translation and found it to be a pseudo-technical report on the world power conference held in Paris about a year ago. Golubtsov really took the Americans to task for having put so much effort and energy into military reactors. This being partly my fault, I took the criticism personally. The Russian quoted at length from a "well-known American economist" who was said to have written a very good exhaustive study of the social implications of atomic energy. The name of this young American economist and scientist was given as James S. Allen, and his book, Atomic Energy and Society.

I got the book; here it is. Let me read some excerpts from it. I am picking at random paragraphs which appealed to me. In one place Economist Allen says: "* * * Science must be freed from its present military shackles and permitted to explore the entire field of atomic energy, which has such enormous implications for all science and for society. The long-term lag of science in the United States can be overcome if it is converted to peace and the traditional principles of freedom of scientific interchange are reestablished" (p. 89).

Now this is a nice thing to come from a Communist stooge. I would like to ask you who are attending this atomic-energy symposium, "How much material did you get from Russian declassified sources?" Since they are so

interested in the peaceful uses of atomic energy, what are they giving you who are also interested in this problem? Why weren't meetings like your symposium held in Russia? Where, for example, is the Russian Smyth report? We haven't seen anything of that; yet the Russians are working only on peaceful uses of atomic energy. What isotopes for medical research has Russia distributed? What assistance has she given the smaller nations in the construction of research reactors? I just cannot take this paragraph very seriously.

Here is another of Allen's paragraphs: "* * * The Soviet Union enjoys much greater freedom and flexibility in the exploitation of new techniques than our country. Whereas we are handicapped by numerous obstacles, such as vested interests in obsolete techniques, monopoly control of entire economic sectors in our economy, and the curse of excess capacity. The Soviet Union can utilize atomic power or atomic propulsion in accordance with established economic goals, and the resources and skills are immediately available" (p. 77). This certainly sounds fine, but where are the reports? No military secrets in Russia, remember.

Here is another quotation which hits painfully close to home as far as we physical scientists are concerned. I have stated that, as scientists, we have been pretty naive politically and that we have been *used* by the Communists. I cite this as evidence. In his preface Allen says: "* * * Original material, reprints, and controversies appearing in the earlier issues of the Bulletin of Atomic Scientists, of Chicago, have proved useful, but this magazine is now *losing its worth* as an organ of discussion because of its increasing coordination with the official position" (p. 8).

So the Bulletin was extremely useful to the Communists in the early days but it is no longer useful. So says James S. Allen. Now, who is James S. Allen? I assumed he was of some stature and tried to locate him in the directory of the American Economic Association and other listings at the library. Strangely, I got the answer out of the newspaper.

Here is the item from the New York Times of Friday, August 3, 1951: "Mrs. Hede Massing, confessed Communist spy and former wife of Gerhard Eisler, testifying before the Senate Internal Security Subcommittee, said, 'One letter dated February 27, 1939, was addressed to James S. Allen, 508 West One Hundred and Thirty-ninth Street, New York. The other was addressed to Max Granich, also of New York.' Mrs. Massing said she had known Mr. Allen under his real name, Sol Auerbach, and that he had been an open member of the Communist Party."

Now this completes the story, but isn't that a neat play? Golubtsov writes an article in Russia, quoting a supposedly well-known American economist, James S. Allen, who actually is their own man, Sol Auerbach, over here writing just what they want to quote. This is what we are up against. It is not going to be easy to hold our own for freedom of speech and the other liberties we prize with that kind of skulduggery to contend with.

We are in a real and a hazardous struggle between two sets of ideas on the nature of the physical world and on the ways that men and nations ought to follow in their relationships with one another.

I do not think we have to worry too much about keeping ahead of the Russians. They may be good; it is a mistake to underestimate them. But we are pretty good, too, and our system is better, so we can hold our own on even terms at any time.

The looming danger is that, lagging behind in the conflict of ideas and systems, our rivals may resort to arms. That these two nations might sometime find themselves in armed struggle is not a new idea. The fundamental nature of this struggle between the rival systems of freedom and despotism has long been recognized.

I was impressed recently by a quotation I found in a magazine. I would like to read it to you.

"It requires no sage to predict events so strongly foreshadowed to us all; still 'Westward will the course of empires take its way.' But the last act of the drama is yet to be unfolded; and notwithstanding the reasoning of political empires, westward, northward and southward, to me it seems that the people of America will, in some form or other, extend their dominion and their power, until they shall have brought within their mighty embrace multitudes of the islands of the Pacific, and placed the Saxon race upon the shores of Asia. * * * The Saxon and the Cossack will meet once more in strife or in friendship in another field. Will it be friendship? I fear not. The antagonist exponents of freedom and absolutism thus meet at last, and then will be fought that mighty

battle on which the world will look with breathless interest; for on its issues will depend the freedom or the slavery of the world—despotism or rational liberty must be the fate of civilized man. I think I see in the distance the giants that are growing up for that fierce and final encounter. In the progress of events that battle must sooner or later inevitably be fought."—Commodore M. C. Perry, March 6, 1856.

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7. ATOMIC ENERGY: WHEN? WHERE? HOW MUCH?

[An interview reprinted from Chemical and Engineering News, American Chemical Society, September 15, 1952. Reprinted by permission]

Today a new industry faces us, an industry that has been predicted will unleash a force which will have a profound effect on the energy pattern of the world. What are the real potentialities? When will a flick of the switch call on an atomic power plant? Where will be plants be located? Certainly statements as to what atomic power will and will not do have been as divergent as black and white.

About a year ago it was stated that the AEC was at an interim point in its reactor program and that the program was again being examined. What plans considered then have resulted in decisions to construct or develop new reactors?

A. Following the program that grew out of the early thinking and was established by the AEC in 1948, we are now in an interim state in that now new large construction projects have been authorized. The Experimental Breeder Reactor and the Materials Testing Reactor are built; the Naval prototypes of submarine nuclear power plants are being built. An exception is the less advanced aircraft program for which test facilities were authorized recently. These will be located at the National Reactor Testing Station in Idaho. Of course, the new reactors are in use all the time, and by research and development we are constantly investigating new reactor ideas and possibilities. Also, it is important to keep in mind that a progressive reactor development program is continuously modified and changed. As our facilities expand, as more scientific and technical talent becomes available, as new knowledge is acquired, and as experience with operating reactors is acquired, we can shift emphasis, change priorities, and undertake new projects.

As an example, I would like to refer to the studies which got under way a little more than a year ago by a group of eight industrial firms, working in four teams of two each, to begin to establish some basis on which they might enter into the business of producing power from nuclear fuels using their own money. Reports have been submitted by these four teams. Out of these studies may come one or more reactor projects to produce power as a coproduct—in the language of one study group—with fissionable materials. Before we establish a large-scale Government-financed AEC reactor program, it is only prudent to see how the industrial program evolves.

Q. Dr. Kenneth Pitzer, former director of AEC's Division of Research, has stated, "Slowness (in building a power reactor) * * * came * * * from an unwillingness * * * to proceed with (any design) until all of the advisers agreed that this was the best design." Dr. Pitzer contrasts this to the wartime attitude during which both routes were followed if major disagreements arose. Bombs were produced within three years, yet six years elapsed after the war before the Experimental Breeder Reactor produced electricity at a rate of 100 kw. Has the program been unduly slow?

A. If you ask me if the reactor development program has moved as rapidly as the Congress, the President, the Commission, the military, the General Manager of the Commission, or I want it to move, the answer is "no." You ask if it has been unduly slow. The answer is "no" to that, too. Though the program may be criticized for other things, I don't see how any program that builds up in three years from approximately $50 million per year to more than $100 million can be called slow.

Q. What are the factors which affect the speed of the program?

A. There are a great many factors which affect the speed of reactor development work. One is the necessary and proper very high priority which the Commission has put on the production of fissionable materials for weapons. Another is the time it took to provide the facilities we needed. A third is the consideration which must be given to factors of cost, safety, and efficient utilization of fissionable materials when measured against the actual results to be obtained from a given reactor development experiment. Remember, we are not talking about laboratory bench work. We are talking about experiments (research and devel-

opment for new types of reactors and the first models) which may cost anywhere from five to fifty million dollars each.

In general, in response to a query as to whether the program for the development of atomic power has moved slowly, the answer obviously appears to be "yes," if you use as a yardstick the number of machines we have producing electric power. But if you take into account the fact that the United States is particularly blessed with reserves for cheap, conventional power, so that this was not one of our urgent objectives, and if you apply a yardstick of real scientific and engineering accomplishment and measure the filling of the reservoir of knowledge and experience on which the future development of power depends, then I say our program has moved at a constantly increasing rate. Certainly today it has considerable momentum.

Q. Dr. Pitzer further states that in recent conversations with defense officials he has been impressed by the increased interest in the over-all atomic development program. What has been the basis for this increased interest and when did it occur?

A. I came to the Atomic Energy Commission from the Research and Development Board of the Department of Defense. When I was with the Board a few years ago, I found even then that there was a very intense interest in atomic energy among the military, but very few of the military men had had an opportunity during and immediately after the war to become familiar with the subject and to appreciate its potential beyond what they knew about its use at Hiroshima and Nagasaki. Today, thousands of men in the military are qualified in this field. It would be hard for anybody to say when this change occurred because it has been occurring constantly since the war. Hundreds of officers and military technicians have been trained in Commission laboratories, many others in the service schools. I feel that what Dr. Pitzer interprets as an increased interest is really an expansion of both the numbers and the knowledge of the people in the military who are concerned with the military applications of atomic energy.

REACTOR DEVELOPMENT

Q. When did the development of power reactors and power-production reactors begin? By a power reactor we mean one that produces power exclusively and by a power-production reactor, one that produces both power and fissionable materials.

A. It would be hard to say when development started on any of these things. In fact, thinking and research on these problems date from the discovery of the fission process itself in 1939. The prewar article by Flugge in *Naturwissenshaften* in 1939 in which both explosive and controlled chain reactions are discussed is illustrative. You may recall that during 1939 the general subject of fission was the chief topic of more than 100 articles in scientific journals in England, Russia, Germany, France, Italy, and the United States. Atomic power was being studied at the U. S. Naval Research Laboratory and doubtless elsewhere when World War II broke out. During the war both the Army air people and the Navy considered the possibilities of nuclear propulsion but deferred action.

Some experimental work was done on power problems in the late stages of the war and early in 1946. One of the earliest projects was one by Dr. Farrington Daniels at Oak Ridge for a power reactor, which was quite a straightforward, direct approach to the problem. It soon became clear, however, that we needed to know a lot more about the behavior of various materials under the unusual conditions of stress which exist in a reactor. There is also some question as to what might be the actual accomplishment, or what we might prove, by simply a demonstration, that the heat taken from a reactor could be utilized to make power.

Various studies of the power problem were carried on through the 1946–1947 period, during which plans were made—first by Manhattan Engineer District and later by the newly created Commission—for a vast expansion of our research facilities to permit the work to go ahead. The expansion which followed included establishing Knolls Atomic Power Laboratory at Schenectady and the construction of Argonne National Laboratory to replace the scattered and inadequate wartime facilities of the old Metallurgical Laboratory at Chicago. Later, the Bettis Plant in Pittsburgh was built, and the National Reactor Testing Station started in Idaho.

Q. What program was laid out during the early postwar period?

A. I was not in the program at that time, but it was quite clear that one of the most pressing requirements was for a reactor in which we could test materials

under conditions of high radiation to get the information needed. This need resulted in the Materials Testing Reactor which went into service this summer at the Testing Station. The MTR is one of our most important resources in this program and provides us with neutron intensities and testing space never before available. We have, of course, used the very fine Canadian reactor at Chalk River, which is a heavy water research reactor based on the original heavy water reactor at Argonne National Laboratory.

The program laid out at that time also called for intensive investigation of the problem of "breeding." This is the term applied to the theoretical possibility of a fission chain reaction which will actually produce more fissionable material than is consumed in the process. Two independent attacks on this important problem, one by Argonne and one by Knolls, were planned at that time.

A third major element in that program was the development of a reactor for submarine propulsion. The Navy was instrumental in starting investigations toward nuclear propulsion at Oak Ridge and at General Electric in Schenectady. In 1948, the Oak Ridge project was transferred to Argonne and became the Submarine Thermal Reactor project. The work at Schenectady eventually expanded into the Submarine Intermediate Reactor project.

In those early years, through arrangements with MED, the Air Force started investigations at Oak Ridge by the Fairchild Engine and Airplane Corp. in the NEPA, or Nuclear Energy for Propulsion of Aircraft, project.

Q. At one time the Intermediate Power-Breeder Reactor was part of the reactor program. Among the reasons given by the AEC for this reactor was that the AEC hoped the reactor would lead to production of central station or industrial power in the "distant" future. Yet work on this reactor was deferred in 1950 in favor of work on the Submarine Intermediate Reactor. What was the reason for that deferment?

A. When we first started the Intermediate Power-Breeder Reactor project at Schenectady, we thought we could take a big jump and build a reactor operating on neutrons of intermediate energy levels and at the same time make it breed and produce power. General Electric carried the project far enough along to see that this was a big job to do all at once. In view of the Navy's established requirement for submarine propulsion systems and the darkening international situation, it was decided to make the first intermediate reactor one for submarine propulsion and not attempt in the same experiment to combine breeding with an effort at economical power.

Q. How has this shift affected AEC's contribution to production of central station or industrial power?

A. I doubt if it has affected the power picture much one way or another. What we must remember about the mobile military reactors is that they may make a very substantial contribution to future power reactors of any kind. Demonstration and use of high-cost power is a step toward lower cost power. The nuclear power plant for a large ship on which Westinghouse is beginning development work will more nearly resemble a central station installation than the submarine plants.

THE PART FOR ATOMIC ENERGY

Q. When we speak of atomic power, the end result as far as central station power is concerned will be "heat-to-steam-to-electricty." In 1951, the U. S. generated about 400 billion kw.-hr. of electricity, about 75 percent of which was thermal power from chemical fuel—coal, gas, and oil—and 25 percent hydroelectric power. The application of atomic energy as envisioned at the present time, therefore, will be to replace or expand the thermal facilities. About 80 percent of the U. S. central station power, excluding electricity generated by firms for internal consumption, is accounted for by private utility companies. Of the $21 billion these companies have invested in their entire system for generation and distribution of power, only 17 percent is invested in the thermal part—the equipment necessary to convert the heat content of the fuel into steam and to deliver the steam to the turbine throttle. This would indicate that in terms of investment the atomic energy part of central station power will not in reality be as large as might be expected?

A. Very definitely. At best, or at most, atomic energy will replace only the firebox and boilers of conventional plants and therefore simply cannot have a revolutionary effect on our industrial economy. This is contrary to the popular misconception that we are seeking a secret process of some kind which will miraculously make electric power free to the consumer.

Q. Of the total cost of delivering power to the consumer at the present time, about 22 percent is accounted for by the cost of operating the thermal facilities. Therefore, when power from atomic energy becomes a reality, there will be no startling changes in the cost of power, at least in the foreseeable future?

A. This is really a continuation or extension of the previous question. Even if engineers somehow did succeed in putting power on the bus-bars of the central station "for free," the consumer, or someone, would still have to pay for transmission and delivery costs. However, I am fully convinced that there will be a market in the United States for all the power that we can produce from nuclear fuels at a cost anywhere comparable to the cost of power from other fuels. At the same time, I am certain the development of systems of producing power from nuclear fuels will not come so fast as to do anything but supplement power from other sources. I do not see that the long term investment of power companies in their facilities is at all endangered. I understand that from 1940 to 1951 the installed electric generating capacity of utilities alone in this country increased from 40 to 76 million kilowatts. If the demand continues to increase at anything approaching this rate, there will be plenty of room for nuclear power plants alongside coal and oil plants rather than in place of them.

Q. How large will individual public power plants be?

A. Here, as in other industrial activities, quantity production reduces unit costs. Hence, I believe it is safe to say that, by standards of experience to date, nuclear power plants will be big. On the other hand, it is entirely possible that some day we may be able to utilize nuclear fuels in what somebody has called "package" power plants of, say 50,000 kw. of electric generating capacity. This isn't very big, but neither is it small. These are units which might be used in isolated locations where costs of hauling fuel are abnormally large.

The direction of our work now indicates, I believe, that the technical problems related to efficient burn-up of fuel and the cost of processing fuel will weigh on the side of big plants. For purposes of this discussion, I would say a big plant is anything above 250,000 kw. of installed electric generating capacity.

THE PRICE OF ATOMIC POWER

Q. Detroit Edison Co. calculates that its 625,000 kw. (installed electrical capacity), coal-fired plant now under construction will deliver one million B. t. u. to the turbine throttle for 57.7 cents and that the investment per kilowatt of electrical capacity will be $77. The company estimates that the investment for a nuclear power plant would be $277 per kilowatt of electrical capacity to deliver one million B. t. u. to the throttle for 57.7 cents under the most ideal conditions of "no fuel cost and no operating labor or maintenance expense for the reactor." As the cost of the nuclear fuel increases, the amount available to invest in the reactor diminishes and reaches zero when the cost of the purified uranium fuel becomes $83 per pound. What do the AEC figures show?

A. I don't believe I can handle this one without a lot of study and tightrope walking because of the security aspects involved. I would like to point out, however, and I am sure Detroit Edison would agree with me, that such figures as those given for the nuclear plant may be very valid today and quite unrealistic tomorrow. However, I think one would be safe in assuming from such figures that there is still a lot of work to be done to make nuclear fuels competitive with chemical fuels.

Q. As a matter of fact, we are not talking today about competitive cost without considerable credit being received from the sale of plutonium, are we?

A. Here we are deeply in the economic side of the problem. I like a statement I saw recently in *Electrical World* to the effect that atomic power can be feasible without being economic. We are trying to be realistic about these things and recommend only such projects as are practical or so close to practical that pilot models can be justified.

Q. John Grebe, of Dow Chemical Co., has stated that his company wants no part of a program based on military subsidy. The sale of plutonium or U–233 is not inherently restricted to the Government, is it?

A. I assume you refer to Mr. Grebe's statements early in his consideration of these problems indicating his interest in a demonstration of the economic practicability of taking power from nuclear reactors without dependence on the sale of its coproduct, the fissionable material produced for weapon purposes. He would like to see a demonstration in which the fissionable material produced would be used only as additional fuel for reactors in order to get economic

data without the influence of war demands. In that sense, the sale of plutonium or U–233 is not inherently restricted to the Government for weapon purposes, but could be used to fuel reactors. Of course, you will recall that the law now provides for Government ownership of all fissionable materials—uranium–235, uranium–233, and plutonium—and for Government licensing and control of all fertile materials—uranium–238 and thorium.

Q. When this power-production program begins and the AEC "buys the plutonium," that is, pays for its manufacture on a unit price basis, how will the price be determined?

A. This is one of the toughest problems we have. I honestly don't know.

Q. What will be the cost of electricity generated by atomic energy plants?

A. If I could answer this one, the brainwork and manhours being invested in this business by the Commission, its contractors, and concerned industrial groups could all be put somewhere else.

WHEN, WHERE, AND HOW MUCH

Q. C. G. Suits, director of research for General Electric, says that the present justification for producing energy from atomic power is not because of a lack of other fuels but because of the need for (1) mobile, military reactors and (2) plants to produce both power and fissionable material. Then he feels the experience gained from (1) and (2) may eventually lead to economical central station power. Do you feel this is correct?

A. To date this has been substantially true.

Q. Various predictions have been made as to when we will have power from atomic energy:

Ten years will be needed to get the facts (Suits).

There will be no considerable power for 20 years (AEC, 1948).

Full scale production is 4 to 5 years away (E. J. Putzell, Monsanto Chemical Co.).

What seems to be the reason for such divergent views?

A. As often happens, the different people are really talking about different situations from different points of view and with different personal biases and motivations. The AEC report refers to the over-all power picture of the nation and states that atomic power will not be providing any considerable percentage of the power supply before the expiration of 20 years. The electric power generating capacity of the United States is so enormous that in order to increase it 10% we would have to build a few score of our largest reactors, which would be quite a chore. On the other hand, Putzell was giving the time to complete development and construction of one unit which we could all hope would be economical and practical but on which the risk of failure is still so great that it would have to be underwritten by taxpayers' money.

Q. If conventional fuels are adequate for at least 25 years, as the President's Materials Policy Commission reports, why are industrial firms so excited over atomic power at this time?

A. Regardless of the adequacy of the conventional fuel supply, and estimates vary, I believe all of the Commission's contractors and all of the industrial groups studying the possibility of entering the business of trying to make power from nuclear fuels will agree there is a great deal to be gained. Perhaps the gain is, at this time, intangible in some respects; but the advance in technology covers many fields of interest to industry—far beyond the utilization of nuclear fuels. Of course, the use of radioactive and stable isotopes is giving a great impetus to the development of industrial technology of all kinds. However, I believe this increasing interest is mainly a normal and inevitable result of the advance in technology, of the initiative and capability of American industry to capitalize on this advance, and the natural and obvious concern of industry never to be asleep at the switch, especially when the birth of a great new industry appears imminent.

Q. Charles Thomas, president of Monsanto, has said that he envisions atomic-energy plants to be best suited for remote western regions. Do you believe this to be the brightest immediate prospect?

A. One of the primary advantages of nuclear fuels is concentration of energy contained in a unit of fuel. Naturally, such a fuel should have first call at any location to which the transportation of conventional fuels is a major factor of cost. Of course, as we discussed earlier, the advantage of concentrated fuel is offset by the presently indicated much greater capital costs for a nuclear power plant. Let us put it another way: Since electricity is, or would be, high in areas

isolated from conventional fuel, such locations are attractive for electricity from nuclear energy.

REACTOR TECHNOLOGY

Q. Reactors currently in operation or definitely under construction all seem to be variations on a theme: Neutron speed—slow, intermediate, fast; fuel—natural or enriched uranium; fuel loading—heterogeneous or homogeneous; materials of construction—graphite, heavy water, deuterium, or beryllium as moderators, for example; coolants—gases, water, molten metals. For the immediate future and for the more distant future, what do the prospects seem to be: continued, empirical variations or reactors involving new features?

A. These are only some of the variables which add up to literally scores of possible combinations. This may be one reason why we seem to go a bit slow at times. When you consider the cost of a big reactor complex, it pays to investigate all of these possible combinations in order to develop the firmest possible basis on which to make a decision. Certainly our work in recent years has narrowed the field somewhat, but it has also called for more exhaustive study of a few new combinations. I don't see how new reactor types can be designed without selection of neutron speed, type of fuel, manner of loading and moderating, cooling and structural materials.. Yet, getting new reactors developed, built, and operating involves far more than empirical variations.

[Editor's Note: Power from fusion is one possibility for new reactors. Dr. Kenneth Pitzer told C&EN in answer to an inquiry as to what the possibilities are that good ground work is being laid in the field. Pure science is progressing satisfactorily and properties of certain reactions are well known. Before useful power can be generated, someone will have to invent some machine analogous to the nuclear-fission reactor. This may or may not be a cyclotron-type machine. Though there have been some rays of hope, there has been no satisfactory invention in this area to his knowledge to date.]

Q. Problems to be solved before atomic energy for power becomes a reality have included the following, as announced from time to time: Remote control, fuel processing, coolants, heat exchange, waste disposal and sanitation, shielding, ore processing, materials of construction. How far along are we toward solving them?

A. I hope you won't think I'm trying to be facetious if I say all of them have been solved in part. There is no single solution to any of them, and all of them are still outstanding.

Q. Which ones will result in the greatest percentage saving in costs when better materials or methods are found?

A. The greatest saving can be made not by nickel and dime savings in the current procedure but by the choice of a basic reactor design which eliminates or reduces nearly to zero the present high costs in the supporting operations. This is why we are exploring so many radically different reactor designs so exhaustively. The homogeneous reactor is an example of how a reactor choice might change completely the chemical processing problem.

PERSONNEL

Q. Trained personnel in what particular disciplines are needed today and in the future?

A. We need mathematicians, theoretical physicists, experimental physicists, chemists, metallurgists, chemical engineers, electronics experts, electrical engineers, heat engineers, mechanical engineers, civil engineers, radiobiologists—you continue the list.

Q. What is being done to get the type required?

A. A great deal is being done to train these men. The Commission works with colleges and universities to enable them to design their curricula to meet the requirements. For example, a number of activities are carried on through the American Society for Engineering Education to help get new subject matter into the curricula. The national laboratories work closely with colleges and universities in their areas. One liaison organization is the Oak Ridge Institute of Nuclear Studies, which is sponsored by 30 educational institutions in the South and Southwest. Nearly 1,200 fellowships awarded by AEC over the past four years aid in training teaching as well as research talent. Source books of information for textbook writers, educators, and students are prepared by AEC for publication.

One of the things that is a specific AEC activity is operating a school in reactor technology at Oak Ridge. Graduates of this school are pretty well spread throughout industry today. The school makes possible instruction in classified subject matter. College credit is given for certain classified classes at Los Alamos Scientific Laboratory.

As far as the training of most men is concerned, it would be difficult to separate the demands of the atomic energy program from the total demands of the country. In a discussion of this subject we had with a group of educators, Dr. Robert J. Oppenheimer observed that he was not so much interested in nuclear engineers as he was in good engineers. We need good men and lots of them in all these fields. A recent survey shows that approximately 14,900 scientists and engineers work for the AEC and its contractors, nearly 95% being with the contractors. This figure excludes construction engineers whose work ends when the construction is completed. It is expected that this number will increase a few thousand during the next few years. When replacements are included, employment of scientists and engineers will considerably exceed the increment. These figures represent scientific and engineering manpower for the entire atomic energy program, of which reactor development amounts to about 20%.

Q. After an initial, small, power-producing experiment in December 1951, the Experimental Breeder Reactor has been investigating the possibility of breeding for some eight months. What can you tell us as to the status of this experiment?

A. As I indicated at one of the Commission's press conferences last winter, we probably will have very little to say about the results of the breeder experiment. As you know, success in the investigating of breeding is an item of the highest security importance.

Q. How adequate are uranium and thorium reserves?

A. The outlook today is more encouraging than it was five years ago. We know there is a lot of uranium in the earth's crust, and we have had increasing success in uncovering new sources of fissionable material.

[EDITOR'S NOTE.—Palmer Putnam has made a broad study of energy sources, reserves and demands for the AEC. In compiling his figures, he has used a new unit, *Q*, which he defines as 10^{18} B. t. u. His conclusions are as follows:

1. World consumption of energy for all purposes up to 1860 amounted to 7*Q*. By 1947, this figure had risen to 12*Q*, and it is estimated that by A. D. 2000 world consumption will have totaled 30*Q*.

2. Our known oil and gas reserves amount to 0.4*Q* and our coal reserves to 68*Q*. However, of the coal reserves, only about 6*Q* can be mined economically by present standards.

3. Total energy available from uranium, assuming we are successful in "breeding," amounts to 100*Q* from the ores which can be mined economically.

One-third of the energy demand in the U. S. has been estimated to be electrical energy demand, the balance being for other uses. Thus it can be seen that uranium, used only for generating electric power can play a substantial role in energy requirements for many years. It can, for instance, prove to be the means of tiding us over until we learn to utilize solar energy, the source predicted to be the real power source of the future.]

Q. A high fuel-burn-up reactor has been mentioned as a potential solution to fuel problems. What have you learned so far?

A. There is not very much I can give you on this one, except to say that in some types of reactors the extent to which fissionable material is actually burned up, or depleted, is a key factor in determining whether a reactor is to produce power primarily, with fissionable material as its byproduct, or fissionable material primarily, with power as its byproduct.

In one possible type of high fuel-burn-up reactor, plutonium would be produced from U^{238}, but instead of being removed from the reactor and extracted by chemical processing, it would remain in the reactor and serve as fuel to keep the chain reaction going as long as possible without removal of fuel elements. The less frequent chemical processing would make for economy.

INDUSTRIAL PARTICIPATION

Q. In the past, industrial participation in the atomic energy program has been limited to those few large companies operating AEC facilities on cost-plus contracts. AEC has stated that its desire is to have industry enter the program on a competitive basis. What talents does industry have to offer which makes this desirable?

A. I would like to modify the first sentence of the question. Of course, the conspicuous examples of industrial participation of the past have been the

large plants and laboratories operated by big companies. At the same time, these few organizations have had numbers of subcontractors. Subcontractors have an increasingly important share in the development of new reactors. For example, Westinghouse has had 3,000 subcontractors on the Submarine Thermal Reactor. While most of them have had small jobs, the number does include development of important components of the nuclear power plant.

The talents required of new industrial participation contractors, operating on a competitive basis, are the same as those of industries which now operate our facilities and carry on research and development work under contract. Their talents include organization and management skill, technical competence, initiative, and many other things. The new groups which are studying the problems now, however, have in addition an incentive, or direct business interest. They are in the business of selling power, designing and building power plants, or making the equipment for power plants, or they are interested in getting into the business as nuclear power emerges.

Because of the nature of the operation, prime contractors running the laboratories and plants work on a cost-plus-fixed-fee basis and do not invest their own funds. The industrial participation arrangement is an effort to attract private investment in reactor plants on such a basis that initiative and efficiency would result in profit—the usual effective incentive of private industry.

Q. In June 1950, Charles Thomas announced his company's interest in participating in the atomic energy program in a role other than that of a contractor. Was this the first public evidence of such an interest on the part of industry?

A. I would not say it was the first sign of industrial competitive interest. Dr. Thomas, himself, in the fall of 1946 reported to the American Chemical Society on a survey he and others had made for the United Nations Atomic Energy Committee estimating the cost of nuclear power. There is considerable literature on the economics of nuclear power. Ward F. Davidson, of Consolidated Edison Co., was an early examiner of possibilities; so was J. R. Menke, then of Kellex Co. There were others. The Industrial Advisory Group (Parker Committee) in 1948 and the Ad Hoc Advisory Committee on Cooperation between the Electric Power Industry and AEC (Sporn Committee), 1949 to 1951, were additional expressions of industrial interest in atomic energy. I would say the initiative shown by the particular groups which came in on the first round of industrial studies was a culmination rather than a first sign of interest.

Q. Four groups participated in that first study. Were these the only companies which evidenced interest or were there others which were not included?

A. Two other companies were very much interested in starting such a study at that time. One was Westinghouse, which was already deeply involved in the atomic-energy program and was carrying a very heavy load of work. The Commission felt that the Westinghouse engineers and scientists and the company's facilities should be equally available to all of the interested concerns, and therefore, asked Westinghouse not to start such a study on an individual-company basis at that time. The company very graciously agreed to this and has cooperated in every possible way with the newcomers.

The second company was Consolidated Edison Co. of New York. By the time the Consolidated Edison proposal came in, we had already accepted proposals from four teams and felt that we could not efficiently handle any more.

Q. These groups have now submitted their recommendations. The Dow-Detroit Edison group proposes that joint research with AEC be undertaken to develop a dual purpose breeder reactor of advanced design. The study is to be undertaken in AEC and the group's facilities, and the group has indicated that it will spend about $250,000 for its part.

Monsanto-Union Electric, on the other hand, is interested in a short range development and has proposed design of a pilot plant concurrently with component development tests. With encouraging results, the pilot plant would be built, if then considered necessary, as a step toward a large plant. Are these proposals contradictory and must the AEC select one or the other?

A. I would not call the proposals contradictory. They are parallel. They follow different lines of development—one being a line in which we have had more experience than the others.

We have decided to go ahead with the Dow-DE group because the data to be developed on the basis of a rather modest expenditure, shared by the companies with the Government, are data which we would eventually have to go after anyway. The Government's part is about $750,000.

Should there be several contracts along the lines of the one with the Dow-DE group, the AEC may at some point and time have to make a selection among

the several proposals before it. The factors that must be weighed cover every possible consideration of national defense and both the short- and long-range contribution of the atomic energy program to the Nation's strength. For the most part, these factors are measured in terms of dollars, not always in terms of numbers of dollars alone, but in terms of the ratio of dollars to results. The more industry contributes in money and talent, the more the over-all program will be advanced.

Q. What have the other 2 groups proposed?

A. The four proposals differ as to the types of reactor designs that would be followed and the financial arrangements. It is planned that the Commission will make public more information soon.

Q. Two of the companies in the first study teams, Monsanto and Dow, are primarily chemical companies, but they are motivated by being rather large consumers of power. Have any other large electricity-consuming industries, such as the aluminum industry, evidenced interest in the program?

A. Yes, of course, the power-consuming industries are interested as customers, but they look to the electricity generating people to carry the ball, and doubtless the utilities which are making these studies have been encouraged to do so by their big customers. I believe it is safe to say that all who are interested in power—whether as producers and sellers of fuel, as manufacturers of equipment, as sellers of power, or as users of power—have shown an interest in the program.

Q. If none of these other large users have taken an active part, however, such as Dow and Monsanto have, chemical companies must have an additional motive for getting in the program?

A. Mr. Putzell, of Monsanto, gives two additional reasons: (1) reactor operation is essentially a matter of chemical engineering, he says; and (2) Monsanto believes that it, a private industry, can produce plutonium at lower cost than the government. To those I would add that chemical companies are logical processors of isolated minerals requiring power for their development.

Q. Information made available to these study teams has been compiled at public expense. How is the AEC making certain that all companies will have equal access to the information available?

A. We are doing everything we can to see that information is made available on an equitable basis. All the industrial participation contractors had access on the same footing to all AEC information on reactor technology. Equal opportunity has been given all qualified firms to take part in this program. With reference to firms getting contracts for various kinds of work, they are given access to the classified information they need to carry on their work.

There is another group which presents a problem in any classified activity—firms which want to examine certain classified activities to find out if they might not be able to render a service. We cannot give clearances for this purpose; there would be too many. It is unfortunate but just one of the problems of classification we are still working on.

Q. What is being done to speed up the declassification of information?

A. Continuing efforts must be carried on to declassify information which is needed by designers and engineers throughout American industry if we are to have a strong atomic energy program. Certainly this is the Commission's position. Declassification goes on all the time and the amount of material that has already been declassified is tremendous. But we have reached the stage in the declassification process where the additional data desired by industry are definitely in the borderline security area. This presents very difficult questions in making a determination as to when the release of information will aid our own program more than the enemy's. We are aided materially in declassifying information useful to industry by an advisory committee of industrialists, principally representatives of technical societies and publications, who visit laboratories and plants to identify information which would be of value to industry and should be submitted for declassification. The committee also recommends the most appropriate means of publication.

APPENDIX D

The following is material arranged chronologically having to do with reactor development and atomic power. No responsibility is assumed for the accuracy or validity of any statement or opinion that is contained herein.

1. THE FIRST PILE

(By Corbin Allardice, Director of Public Information Service, United States Atomic Energy Commission, New York Operations Office, and Edward R. Trapnell, Associate Director, Division of Public and Technical Information Service, United States Atomic Energy Commission, Washington, D. C.)

On December 2, 1942, man first initiated a self-sustaining nuclear chain reaction, and controlled it.

Beneath the west stands of Stagg Field, Chicago, late in the afternoon of that day, a small group of scientists witnessed the advent of a new era in science. History was made in what had been a squash-rackets court.

Precisely at 3:25 p. m., Chicago time, Scientist George Weil withdrew the cadmium-plated control rod and by his action man unleashed and controlled the energy of the atom.

As those who witnessed the experiment became aware of what had happened, smiles spread over their faces and a quiet ripple of applause could be heard. It was a tribute to Enrico Fermi, Nobel prize winner, to whom, more than to any other person, the success of the experiment was due.

Fermi, born in Rome, Italy, on September 29, 1901, had been working with uranium for many years. In 1934 he bombarded uranium with neutrons and produced what appeared to be element 93 (uranium is element 92) and element 94. However, after closer examination it seemed as if nature had gone wild; several other elements were present, but none could be fitted into the periodic table near uranium—where Fermi knew they should have fitted if they had been the transuranic elements 93 and 94. It was not until 5 years later that anyone, Fermi included, realized he had actually caused fission of the uranium and that these unexplained elements belonged back in the middle part of the periodic table.

Fermi was awarded the Nobel prize in 1938 for his work on transuranic elements. He and his family went to Sweden to receive the prize. The Italian Fascist press severely criticized him for not wearing a Fascist uniform and failing to give the Fascist salute when he received the award. The Fermis never returned to Italy.

From Sweden, having taken most of his personal possessions with him, Fermi proceeded to London and thence to America where he has remained ever since.

The modern Italian explorer of the unknown was in Chicago that cold December day in 1942. An outsider, looking into the squash court where Fermi was working would have been greeted by a strange sight. In the center of the 30- by 60-foot room, shrouded on all but one side by a gray balloon cloth envelope, was a pile of black bricks and wooden timbers, square at the bottom and a flattened sphere on top. Up to half of its height, its sides were straight. The top half was domed, like a beehive. During the construction of this crude appearing but complex pile (the name which has since been applied to all such devices) the standing joke among the scientists working on it was: "If people could see what we're doing with a million and a half of their dollars, they'd think we are crazy. If they knew why we are doing it, they'd be sure we are."

In relation to the fabulous atomic-bomb program, of which the Chicago pile experiment was a key part, the successful result reported on December 2 formed one more piece for the jigsaw puzzle which was atomic energy. Confirmation of the chain-reactor studies was an inspiration to the leaders of the bomb project, and reassuring at the same time, because the Army's Manhattan Engineer District had moved ahead on many fronts. Contract negotiations were under way to

build production-scale nuclear chain reactors, land had been acquired at Oak Ridge, Tenn., and millions of dollars had been obligated.

Three years before the December 2 experiment, it had been discovered that when an atom of uranium was bombarded by neutrons, the uranium atom sometimes was split, or fissioned. Later, it had been found that when an atom of uranium fissioned, additional neutrons were emitted and became available for further reaction with other uranium atoms. These facts implied the possibility of a chain reaction, similar in certain respects to the reaction which is the source of the sun's energy. The facts further indicated that if a sufficient quantity of uranium could be brought together under the proper conditions, a self-sustaining chain reaction would result. This quantity of uranium necessary for a chain reaction under given conditions is known as the critical mass, or more commonly, the "critical size" of the particular pile.

For 3 years the problem of a self-sustaining chain reaction had been assiduously studied. Nearly a year after Pearl Harbor, a pile of critical size was finally constructed. It worked. A self-sustaining nuclear chain reaction was a reality.

Years of scientific effort and study lay behind this demonstration of the first self-sustaining nuclear chain reaction. The story goes back at least to the fall of 1938 when two German scientists, Otto Hahn and Fritz Strassman, working at the Kaiser Wilhelm Institute in Berlin, found barium in the residue material from an experiment in which they had bombarded uranium with neutrons from a radium-beryllium source. This discovery caused tremendous excitement in the laboratory because of the difference in atomic mass between the barium and the uranium. Previously, in residue material from similar experiments, elements other than uranium had been found, but they differed from the uranium by only one or two units of mass. The barium differed by approximately 98 units of mass. The question was, Where did this element come from? It appeared that the uranium atom when bombarded by a neutron had split into two different elements each of approximately half the mass of the uranium.

Before publishing their work in the German scientific qournal Die Naturwissenschaften, Hahn and Strassman communicated with Lise Meitner who, having fled the Nazi-controlled Reich, was working with Neils Bohr in Copenhagen, Denmark.

Meitner was very much interested in this phenomenon and immediately attempted to analyze mathematically the results of the experiment. She reasoned that the barium and the other residual elements were the result of a fission, or breaking, of the uranium atom. But when she added the atomic masses of the residual elements, she found this total was less than the atomic mass of uranium.

There was but one explanation: The uranium fissioned or split, forming two elements each of approximately half of its original mass, but not exactly half. Some of the mass of the uranium had disappeared. Meitner and her nephew, O. R. Frisch, suggested that the mass which disappeared was converted into energy. According to the theories advanced in 1905 by Albert Einstein in which the relationship of mass to energy was stated by the equation $E=mc^2$ (energy is equal to mass times the square of the speed of light), this energy release would be of the order of 200,000,000 electron volts for each atom fissioned.

Einstein himself, nearly 35 years before, had said this theory might be proved by further study of radioactive elements. Bohr was planning a trip to America to discuss other problems with Einstein who had found a haven at Princeton's Institute for Advanced Studies. Bohr came to America, but the principal item he discussed with Einstein was the report of Meitner and Frisch. Bohr arrived at Princeton on January 16, 1939. He talked to Einstein and J. A. Wheeler who had once been his student. From Princeton the news spread by word of mouth to neighboring physicists, including Enrico Fermi at Columbia. Fermi and his associates immediately began work to find the heavy pulse of ionization which could be expected from the fission and consequent release of energy.

Before the experiments could be completed, however, Fermi left Columbia to attend a conference on theoretical physics at George Washington University in Washington, D. C. Here Fermi and Bohr exchanged information and discussed the problem of fission. Fermi mentioned the possibility that neutrons might be emitted in the process. In this conversation, their ideas of the possibility of a chain reaction began to crystallize.

Before the meeting was over, experimental confirmation of Meitner and Frisch's deduction was obtained from four laboratories in the United States (Carnegie Institution of Washington, Columbia, Johns Hopkins, and the University of California). Later it was learned that similar confirmatory experiments had been made by Frisch and Meitner on January 15. Frederic Joliot-

Curie in France, too, confirmed the results and published them in the January 30 issue of the French scientific journal, Comptes rendus.

On February 27, 1939, the Canadian born Walter H. Zinn and Leo Szilard, a Hungarian, both working at Columbia University, began their experiments to find the number of neutrons emitted by the fissioning uranium. At the same time, Fermi, and his associates, Herbert L. Anderson and H. B. Hanstein, commenced their investigation of the same problem. The results of these experiments were published side-by-side in the April edition of the Physical Review and showed that a chain reaction might be possible since the uranium emitted additional neutrons when it fissioned.

These measurements of neutron emission by Fermi, Zinn, Szilard, Anderson, and Hanstein were highly significant steps toward a chain reaction.

Further impetus to the work on a uranium reactor was given by the discovery of plutonium at the Radiation Laboratory, Berkeley, Calif., in March 1940. This element, unknown in nature, was formed by uranium 238 capturing a neutron, and thence undergoing two successive changes in atomic structure with the emission of beta particles. Plutonium, it was believed, would undergo fission as did the rare isotope of uranium, U–235.

Meanwhile, at Columbia, Fermi and Zinn and their associates were working to determine operationally possible designs of a uranium chain reactor. Among other things, they had to find a suitable moderating material to slow down the neutrons traveling at relatively fast velocities. In July 1941, experiments with uranium were started to obtain measurements of the reproduction factor (called k), which was the key to the problem of a chain reaction. If this factor could be made sufficiently greater than 1, a chain reaction could be made to take place in a mass of material of practical dimensions. If it were less than 1, no chain reaction could occur.

Since impurities in the uranium and in the moderator would capture neutrons and make them unavailable for further reactions, and since neutrons would escape from the pile without encountering uranium 235 atoms, it was not known whether a value for k greater than unity could ever be obtained.

Fortunate it was, that the obtaining of a reproduction factor greater than 1 was a complex and difficult problem. If Hitler's scientists had discovered the secret of controlling the neutrons and had obtained a working value of k, they would have been well on the way toward producing an atomic bomb for the Nazis.

One of the first things that had to be determined was how best to place the uranium in the reactor. Fermi and Szilard suggested placing the uranium in a matrix of the moderating material, thus forming a cubical lattice of uranium. This placement appeared to offer the best opportunity for a neutron to encounter a uranium atom. Of all the materials which possessed the proper moderating qualities, graphite was the only one which could be obtained in sufficient quantity of the desired degree of purity.

The study of graphite-uranium lattice reactors was started at Columbia in July 1941, but after reorganization of the uranium project in December 1941, Arthur H. Compton, was placed in charge of this phase of the work, under the Office of Scientific Research and Development, and it was decided that the chain-reactor program should be concentrated at the University of Chicago. Consequently, early in 1942 the Columbia and Princeton groups were transferred to Chicago where the Metallurgical Laboratory was established.

In a general way, the experimental nuclear physics group under Fermi was primarily concerned with getting a chain reaction going; the chemistry division organized by F. H. Spedding (later in turn under S. K. Allison, J. Franck, W. C. Johnson, and T. Hogness) with the chemistry of plutonium and with separation methods, and the theoretical group under E. P. Wigner with designing production piles. However, the problems were intertwined and the various scientific and technical aspects of the fission process were studied in whatever group seemed best equipped for the particular task.

At Chicago, the work on subcritical size piles was continued. By July 1942, the measurements obtained from these experimental piles had gone far enough to permit a choice of design for a test pile of critical size. At that time, the dies for the pressing of the uranium oxides were designed by Zinn and ordered made. It was a fateful step, since the entire construction of the pile depended upon the shape and size of the uranium pieces.

It was necessary to use uranium oxides because metallic uranium of the desired degree of purity did not exist. Although several manufacturers were attempting to produce the uranium metal, it was not until November that any appreciable amount was available. By mid-November, Westinghouse Electric

& Manufacturing Co., Metal Hydrides Co., and F. H. Spedding, who was working at Iowa State College at Ames, Iowa, had delivered several tons of the highly purified metal which was placed in the pile, as close to the center as possible. The procurement program for moderating material and uranium oxides had been handled by Norman Hilberry. R. L. Doan headed the procurement program for pure uranium metal.

Although the dies for the pressing of the uranium oxides were designed in July, additional measurements were necessary to obtain information about controlling the reaction, to revise estimates as to the final critical size of the pile, and to develop other data. Thirty experimental subcritical piles were constructed before the final pile was completed.

Meantime, in Washington, Vannevar Bush, Director of the Office of Scientific Research and Development, had recommended to President Roosevelt that a special Army engineer organization be established to take full responsibility for the development of the atomic bomb. During the summer, the Manhattan Engineer District was created, and in September 1942, Maj. Gen. L. R. Groves assumed command.

Construction of the main pile at Chicago started in November. The project gained momentum, with machining of the graphite blocks, pressing of the uranium-oxide pellets, and the design of instruments. Fermi's two "construction" crews, one under Zinn and the other under Anderson, worked almost around the clock. V. C. Wilson headed up the instrument work.

Original estimates as to the critical size of the pile were pessimistic. As a further precaution, it was decided to enclose the pile in a balloon cloth bag which could be evacuated to remove the neutron-capturing air.

This balloon cloth bag was constructed by Goodyear Tire & Rubber Co. Specialists in designing gas-bags for lighter-than-air craft, the company's engineers were a bit puzzled about the aerodynamics of a square balloon. Security regulations forbade informing Goodyear of the purpose of the envelope and so the Army's new square balloon was the butt of much joking.

The bag was hung with one side left open; in the center of the floor a circular layer of graphite bricks was placed. This and each succeeding layer of the pile was braced by a wooden frame. Alternate layers contained the uranium. By this layer-on-layer construction a roughly spherical pile of uranium and graphite was formed.

Facilities for the machining of graphite bricks were installed in the West Stands. Week after week this shop turned out graphite bricks. This work was done under the direction of Zinn's group, by skilled mechanics led by millwright August Knuth. In October, Anderson and his associates joined Zinn's men.

Describing this phase of the work, Albert Wattenberg, one of Zinn's group, said: "We found out how coal miners feel. After 8 hours of machining graphite, we looked as if we were made up for a minstrel. One shower would remove only the surface graphite dust. About a half-hour after the first shower the dust in the pores of your skin would start oozing. Walking around the room where we cut the graphite was like walking on a dance floor. Graphite is a dry lubricant, you know, and the cement floor covered with graphite dust was slippery."

Before the structure was half complete measurements indicated that the critical size at which the pile would become self-sustaining was somewhat less than had been anticipated in the design.

Day after day the pile grew toward its final shape. And as the size of the pile increased, so did the nervous tension of the men working on it. Logically and scientifically they knew this pile would become self-sustaining. It had to. All the measurements indicated that it would. But still, the demonstration had to be made. As the eagerly awaited moment drew nearer, the scientists gave greater and greater attention to details, the accuracy of measurements, and exactness of their construction work.

Guiding the entire pile construction and design was the nimble-brained Fermi, whose associates described him as "completely self-confident but wholly without conceit."

So exact were Fermi's calculations, based on the measurements taken from the partially finished pile, that days before its completion and demonstration on December 2, he was able to predict almost to the exact brick the point at which the reactor would become self-sustaining.

But with all their care and confidence, few in the group knew the extent of the heavy bets being placed on their success. In Washington, the Manhattan

District had proceeded with negotiations with E. I. du Pont de Nemours & Co. to design, build, and operate a plant based on the principles of the then unproved Chicago pile. The $350,000,000 Hanford Engineer Works at Pasco, Wash., was to be the result.

At Chicago during the early afternoon of December 1, tests indicated that critical size was rapidly being approached. At 4 p. m. Zinn's group was relieved by the men working under Anderson. Shortly afterward, the last layer of graphite and uranium bricks was placed on the pile. Zinn, who remained, and Anderson made several measurements of the activity within the pile. They were certain that when the control rods were withdrawn, the pile would become self-sustaining. Both had agreed, however, that should measurements indicate the reaction would become self-sustaining when the rods were withdrawn, they would not start the pile operating until Fermi and the rest of the group could be present. Consequently, the control rods were locked and further work was postponed until the following day.

That night the word was passed to the men who had worked on the pile that the trial run was due the next morning.

About 8:30 on the morning of Wednesday, December 2, the group began to assemble in the squash court.

At the north end of the squash court was a balcony about 10 feet above the floor of the court. Fermi, Zinn, Anderson, and Compton were grouped around instruments at the east end of the balcony. The remainder of the observers crowded the little balcony. R. G. Nobles, one of the young scientists who worked on the pile put it this way: "The control cabinet was surrounded by the 'big wheels'; the 'little wheels' had to stand back."

On the floor of the squash court, just beneath the balcony, stood George Weil, whose duty it was to handle the final control rod. In the pile were three sets of control rods. One set was automatic and could be controlled from the balcony. Another was an emergency safety rod. Attached to one end of this rod was a rope running through the pile and weighted heavily on the opposite end. The rod was withdrawn from the pile and tied by another rope to the balcony. Hilberry was ready to cut this rope with an ax, should something unexpected happen, or in case the automatic safety rods failed. The third rod, operated by Weil, was the one which actually held the reaction in check until withdrawn the proper distance.

Since this demonstration was new and different from anything ever done before, complete reliance was not placed on mechanically operated control rods. Therefore, a liquid-control squad, composed of Harold Lichtenberger, W. Nyer, and A. C. Graves, stood on a platform above the pile. They were prepared to flood the pile with cadmium-salt solution in case of mechanical failure of the control rods.

Each group rehearsed its part of the experiment.

At 9:45 Fermi ordered the electrically operated control rods withdrawn. The man at the controls threw the switch to withdraw them. A small motor whined. All eyes watched the lights which indicated the rods' position.

But quickly, the balcony group turned to watch the counters, whose clicking stepped up after the rods were out. The indicators of these counters resembled the face of a clock, with hands to indicate neutron count. Nearby was a recorder, whose quivering pen traced the neutron activity within the pile.

Shortly after 10 o'clock, Fermi ordered the emergency rod, called Zip, pulled out and tied.

"Zip out," said Fermi. Zinn withdrew Zip by hand and tied it to the balcony rail. Weil stood ready by the vernier control rod which was marked to show the number of feet and inches which remained within the pile.

At 10:37 Fermi, without taking his eyes off the instruments, said quietly:

"Pull it to 13 feet, George." The counters clicked faster. The graph pen moved up. All the instruments were studied, and computations were made.

"This is not it," said Fermi. "The trace will go to this point and level off." He indicated a spot on the graph. In a few minutes the pen came to the indicated point and did not go above that point. Seven minutes later Fermi ordered the rod out another foot.

Again the counters stepped up their clicking, the graph pen edged upward. But the clicking was irregular. Soon it leveled off, as did the thin line of the pen. The pile was not self-sustaining—yet.

At 11 o'clock, the rod came out another 6 inches; the result was the same: and increase in rate, followed by the leveling off.

Fifteen minutes later, the rod was further withdrawn and at 11:25 was moved again. Each time the counters speeded up, the pen climbed a few points. Fermi predicted correctly every movement of the indicators. He knew the time was near. He wanted to check everything again. The automatic control rod was reinserted without waiting for its automatic feature to operate. The graph line took a drop, the counters slowed abruptly.

At 11:35, the automatic safety rod was withdrawn and set. The control rod was adusted and Zip was withdrawn. Up went the counters, clicking, clicking, faster and faster. It was the clickety-click of a fast train over the rails. The graph pen started to climb. Tensely, the little group watched, and waited, entranced by the climbing needle.

Whrrrump! As if by a thunderclap, the spell was broken. Every man froze—then breathed a sigh of relief when he realized the automatic rod had slammed home. The safety point at which the rod operated automatically had been set too low.

"I'm hungry," said Fermi. "Let's go to lunch."

Perhaps, like a great coach, Fermi knew when his men needed a break.

It was a strange "between halves" respite. They got no pep talk. They talked about everything else but the "game." The redoubtable Fermi, who never says much, had even less to say. But he appeared supremely confident. His "team" was back on the squash court at 2:00 p. m. Twenty minutes later, the automatic rod was reset and Weil stood ready at the control rod.

"All right, George," called Fermi, and Weil moved the rod to a predetermined point. The spectators resumed their watching and waiting, watching the counters spin, watching the graph, waiting for the settling down and computing the rate of rise of reaction from the indicators.

At 2:50 the control rod came out another foot. The counters nearly jammed, the pen headed off the graph paper. But this was not it. Counting ratios and the graph scale had to be changed.

"Move it 6 inches," said Fermi at 3:20. Again the change—but again the leveling off. Five minutes later, Fermi called: "Pull it out another foot."

Weil withdrew the rod.

"This is going to do it," Fermi said to Compton, standing at his side. "Now it will become self-sustaining. The trace will climb and continue to climb. It will not level off."

Fermi computed the rate of rise of the neutron counts over a minute period. He silently, grim-faced, ran through some calculations on his slide rule.

In about a minute he again computed the rate of rise. If the rate was constant and remained so, he would know the reaction was self-sustaining. His fingers operated the slide rule with lightning speed. Characteristically, he turned the rule over and jotted down some figures on its ivory back.

Three minutes later he again computed the rate of rise in neutron count. The group on the balcony had by now crowded in to get an eye on the instruments, those behind craning their necks to be sure they would know the very instant history was made. In the background could be heard William Overbeck calling out the neutron count over an annunciator system. Leona Marshall (the only girl present), Anderson, and William Strum were recording the readings from the instruments. By this time the click of the counters was too fast for the human ear. The clickety-click was now a steady brrrrr. Fermi, unmoved, unruffled, continued his computations.

"I couldn't see the instruments," said Weil. "I had to watch Fermi every second, waiting for orders. His face was motionless. His eyes darted from one dial to another. His expression was so calm it was hard. But suddenly, his whole face broke into a broad smile."

Fermi closed his slide rule—

"The reaction is self-sustaining," he announced quietly, happily. "The curve is exponential."

The group tensely watched for 28 minutes while the world's first nuclear chain reactor operated.

The upward movement of the pen was leaving a straight line. There was no change to indicate a leveling off. This was it.

"O. K., 'zip' in," called Fermi to Zinn, who controlled that rod. The time was 3:53 p. m. Abruptly, the counters slowed down, the pen slid down across the paper. It was all over.

Man had initiated a self-sustaining nuclear reaction—and then stopped it. He had released the energy of the atom's nucleus and controlled that energy.

Right after Fermi ordered the reaction stopped, the Hungarian-born theoretical physicist, Eugene Wigner, presented him with a bottle of Chianti wine. All through the experiment Wigner had kept this wine hidden behind his back.

Fermi uncorked the wine bottle and sent out for paper cups so all could drink. He poured a little wine in all the cups, and silently, solemnly, without toasts, the scientists raised the cups to their lips—the Canadian Zinn, the Hungarians Szilard and Wigner, the Italian Fermi, the Americans Compton, Anderson, Hilberry, and a score of others. They drank to success—and to the hope they were the first to succeed.

A small crew was left to straighten up, lock controls, and check all apparatus. As the group filed from the west stands, one of the guards asked Zinn:

"What's going on, Doctor, something happen in there?"

The guard did not hear the message which Arthur Compton was giving James B. Conant at Harvard, by long-distance telephone. Their code was not prearranged.

"The Italian navigator has landed in the New World," said Compton.

"How were the natives?" asked Conant.

"Very friendly."

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2. REPORT OF COMMITTEE ON POSTWAR POLICY, DECEMBER 28, 1944

1. Authorization and membership

On August 29, 1944, after discussion with the Military Policy Committee, Maj. Gen. L. R. Groves appointed a committee "for the purpose of securing a considered recommendation, from a technical standpoint, of the postwar policy for governmental research and development in the field of utilizing the potential atomic energy of uranium and plutonium."

The committee appointed consists of Dr. W. K. Lewis, professor of chemical engineering at the Massachusetts Institute of Technology, Rear Adm. E. W. Mills, Assistant Chief of the Bureau of Ships, USN, Dr. H. D. Smyth, professor of physics at Princeton University, and Dr. R. C. Tolman, vice chairman of the National Defense Research Committee. On the invitation of General Groves, Capt. T. A. Solberg, USN, has sat with the committee to assist Admiral Mills and to serve as his deputy in case of necessity.

2. Basis of information

The technical information on which this report is based was to some extent already available to members of the committee previously associated with the project, to some extent obtained by specific request from General Groves' office, and to a very large extent obtained directly from the principal scientists who have been responsible for the research and development work of the project.

To secure this third type of information the committee invited the directors of the scientific work of the project, together wtih their scientific associates, to appear for interview and also to present such written memoranda on postwar policy as seemed to them desirable. As a consequence the committee has had a total of 45 direct interviews with the directors and scientists responsible for the five principal phases of the scientific work of the project—on the separation of U–235 by diffusion through barriers, on the separation of U–235 by thermal diffusion, on the separation of U–235 by the electromagnetic method, on the preparation of Pu–239 by pile operation, and on the military utilization of U–235 and Pu–239 as high explosives. In addition the committee has received from scientists on the project a total of 37 memoranda on different phases of postwar policy. (A list of the scientists interviewed or presenting memoranda will be found in appendix to sec. 2.) The committee considers that it has received a quite complete statement of the views held by the scientists working on the project as to the technical factors affecting postwar policy.

While principally concerned with receiving opinions on technical matters, the committee has encouraged a full and frank expression by the scientists as to their views on administrative factors affecting postwar policy. It may be remarked that substantially complete agreement among scientists was found as to their views on technical factors and a large measure of agreement as to their views on administrative factors.

The committee has not undertaken any inquiry into the views held by industrialists engaged on the project. Such a study could be made prior to a later report if the committee is so instructed.

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3. Philosophy of the report

The results of the committee's study will be found in the next two sections entitled "Comments on Administrative Matters" and Technical Recommendations." Before proceeding to them, it will be advantageous to make certain remarks as to points of view which have governed the thinking of the committee in preparing this report.

The most important conclusion of the committee is that the military objectives involved in the field properly have overriding importance. The committee feels that as regards the future security of the Nation the military potentialities are great enough to warrant continuing the overriding priority on military objectives into the peace period.

In reaching the technical recommendations made at the end of the report the committee, in accordance with the above conclusion, has regarded the maintenance of military superiority as the primary objective which must dictate present national planning on the utilization of nuclear energy in this country. The first four recommendations of the committee, as to the necessity for further governmental work on the separation of U–235, on the production of Pu–239 and U–233, on the development of military weapons, and on the development of naval power, are evidently directly related to this problem of military protection. In addition, however, the two further recommendations, as to the necessity of adopting vigorous policies of governmental encouragement to fundamental research and to industrial development in the general field of nucleonics, are regarded by the committee as themselves essential to the maintenance of a sufficiently advanced scientific and technical position so that the military protection of the country will be assured. The committee believes that a strong development of the science and technology of nucleonics would in any case be a major national asset.

The technical recommendations made at the end of the report are presented without detailed discussion of the considerations on which they are based or the consquences which they entail. This is done partly in the interests of brevity and clarity of expression, and partly in order to make a first report possible at this time. It is the intention of the committee to amplify the report from time to time by presenting appendixes which include more detailed discussions. In the meantime, the recommendations as made present the well-considered views of the committee on the technical aspects of a proper postwar policy.

In addition to considering the technical matters upon which the committee was specifically asked to report, the committee has also given some attention to administrative questions, since the scientists interviewed have themselves expressed much interest and concern in such matters, and since the possibility of any recommended technical program is itself partly dependent on the administrative framework within which it operates. In view of this interrelation between technical and administrative possibilities, the committee presents in the next section a number of comments on administrative matters, reserving its definite recommendations on technical matters for the final section of the report.

4. Comments on administrative matters

The postwar policy of Government as to the administration of activities in the field of utilizing nuclear energy is a matter of deep interest to all who are concerned with the military safety of the country, and with scientific and industrial development in the general field of nucleonics. Wise decisions as to the nature of this policy, arrived at as soon as may be practicable, would serve to allay anxieties as to the future now expressed by scientists working in the field, and would make it possible to plan for postwar work with minimum losses due to interruption of effort and dispersal of personnel.

Certain administrative features of the present program of work in the field may be commented on as follows:

(*a*) At the present time, the entire program for research, development, production and utilization in the field of nuclear energy is carried out under the immediate administrative control and detailed supervision of Government.

In view of the close relation of work on nuclear energy to national defense, it appears to the committee that postwar work in this field should still remain under the general administrative control of Government.

(*b*) The present agency of Government principally concerned with the direction of the program is the War Department. The actual work is carried out partly by already established Government laboratories, but largely by extensive special laboratories and manufacturing plants which have been set up for the

purpose through Government contracts with universities and industrial companies.

In the opinion of the committee, consideration should be given to the postwar establishment of a special Government authority for the control of funds and distribution of work in the field of nucleonics. This postwar authority should have military as well as civilian members, but it is felt that the project should not be under the immediate direction of the Armed Services except for those developments of a strictly military nature. The agency should determine the distribution of work among Government, military and civil laboratories, academic institutions and industrial organizations. Insofar as security requirements permit, it would appear important to promote supplementary independent scientific and technical developments by academic and industrial laboratories, under the general administrative control but not detailed supervision of Government. The authority should also see that proper steps are taken to survey and insofar as feasible control the sources and supplies of the fundamental materials uranium and thorium.

(*c*) The present program is a very large and expensive one, operated with the purpose of achieving maximum speed rather than economy, and entirely financed by Government.

It appears clear to the committee that the total postwar Government budget for work in the field of nucleonics will have to be much smaller than that which has been appropriate in wartime. Nevertheless, it is felt that fundamental research in the field should be carried on at a substantially undiminished rate.

(*d*) Substantially the sole purpose of the present program is the development and production of powerful weapons for use in the present war.

In the opinion of the committee, postwar policy should be concerned not merely with the development of military weapons, but with the general development of the field of nucleonics including possible peacetime applications.

(*e*) At present the scientific personnel engaged on various phases of this work has been largely drawn from the universities. This has led to a complete interruption of the training of young men in the fundamental knowledge of nuclear physics and chemistry.

In the future it is essential that able young men become interested in nucleonics and thoroughly trained in its fundamentals. The university departments of physics and chemistry must have their strength restored and if possible augmented. Students at all levels must be encouraged. To avoid a serious hiatus in the supply of such men appropriate steps should be initiated now.

(*f*) In the interests of military security, the present program is carried out under a policy which enforces utmost secrecy as to the nature, extent and results of the work and which provides for compartmentalization of effort with severe restrictions on the flow of scientific and technical information between different groups of scientists and industrialists.

The committee expresses approval of the wartime policy of maintaining utmost secrecy concerning work on the utilization of nuclear energy, including restrictions on the flow of information between different groups working in the field. The postwar policy as to secrecy, especially after demonstrated military use of the weapon, can be relaxed in certain aspects to advantage, since a wider dissemination of scientific and technical knowledge will lead to more rapid progress. Nevertheless the committee is of the opinion that much information as to scientific and technical results, as to methods of manufacturing active materials, as to the nature and mode of use of military weapons, and as to locations and time schedules will still have to be kept as secret as practicable in the postwar period. The frequent argument—that the information will leak out anyhow—does not mean that its dissemination cannot be importantly delayed by an appropriate security policy. And the other frequent argument—that military safety depends primarily on keeping ahead in the development of superior nuclear weapons—does not cover the whole story in a situation where even less well-developed weapons may nevertheless be sufficient to produce disastrous results if used just prior to a formal declaration of war. On the other hand the committee emphasizes the stultifying effect of too much secrecy on fundamental research and on the training of young scientists in this field. Hence, in the absence of international agreements to the contrary, the committee believes that a well considered postwar security policy will have to be established in which careful consideration is given to the relative advantages and disadvantages of each proposed disclosure of information.

5. Technical Recommendations.

In the light of the previously stated conviction that military considerations must be paramount in the field of nucleonics, the committee makes the following recommendations as to the technical aspects of the postwar policy of Government.

(*a*) *Separation of U–235.*—The Government should arrange for continued development and operation of the existing plants for the manufacture of U–235, using the methods of diffusion through membranes, of thermal diffusion and of electromagnetic separation, until it has become clear which method or combination of methods is most advantageous. Work on existing plants should be supplemented by research and design studies of possible basic improvements in the separation methods employed which might change their relative advantages. In addition research should be encouraged on the possible separation of U–235 by centrifugal methods, by alternative electromagnetic methods, by chemical exchange processes, or by other methods not now developed. Special attention should be given to processes which might be carried out successfully with such small scale apparatus as to escape notice. The operation of existing plants should in any case be continued for the production of such amounts of active material as are needed for military security, for use in scientific and engineering investigations, and for use in any industrial applications that may be authorized.

(*b*) *Production of Pu–239 and U–233.*—The Government should arrange for continued study and operation of the existing graphite piles for the manufacture of plutonium, until the potentialities of this method of producing active material have become clear. The operation should also be continued to produce plutonium for the previously mentioned military, investigational, and industrial needs. This operation should be supplemented by research and design studies on improved production piles, giving consideration to alternative moderators and coolants. In this connection it is already clear that heavy water would have some important advantages over graphite as a moderator, that the use of beryllium as a moderator must be considered, and that coolants other than air or water present important possibilities. The development work on piles for the production of U–233 which has been started should be continued. The theoretical considerations of the possibilities of the complete burning of uranium and thorium which have been initiated should be continued. Special attention should be given to the possibility that U–233 could be multiplied in amount if allowed to undergo fission in the center of a thorium absorber where fresh U–233 would be produced by neutron capture.

(*c*) *Military weapons.*—The Government should continue the development of nuclear weapons as a project of overriding urgency so long as national security may be endangered. Nuclear fission bombs of greatly improved efficiency are certainly in sight, and thermo-nuclear bombs of ten-thousand-fold greater power may even be feasible. These latter would permit an enemy in a single day preceding declaration of hostilities to carry out an action which might be decisive for the outcome of a war. Studies of the possible use of fission products as radioactive poisons should be undertaken at such priority as is necessary for military security.

(*d*) *Power production.*—The Government should initiate and push, as an urgent project, research and development studies to provide power from nuclear sources for the propulsion of naval vessels. It might be advisable to authorize the initiation of these studies at once, without waiting for the postwar period, in order to utilize scientific personnel already familiar with pile theory and operation. The development of fission piles solely for the production of power for ordinary commercial use does not appear economically sound nor advisable from the point of view of preserving national resources.

(*e*) *Fundamental research.*—The Government should pursue a policy of vigorous encouragement to fundamental research in the general field of nucleonics. Such research should include studies of the physical, chemical, metallurgical and nuclear properties of materials useful as reactants, moderators, and coolants in nuclear chain reactions, or useful for construction, shielding, and control. Research should also include studies of the physics and chemistry of the fission products produced in pile operation, and of isotopes that can be produced by exposure to pile neutrons. Separation methods for the production of isotopes in general from natural materials should also be investigated at the research level. The application of isotopes as tracers and agents in biological and medical research should be pushed. The therapeutic use of isotopes and of radiation from piles should be investigated. Attention should be given to the construction of small enriched piles which would be especially useful for scientific and possible

commercial applications. Above all, however, a strong attack should be made on the basic problems of nuclear structure in order to provide a sound nuclear theory which can be applied to neutron chain reactions, thermo-nuclear reactions, and other nuclear processes. It will be such studies motivated by scientific considerations that may be expected to disclose the most important unforeseen possibilities that lie in the field of nucleonics.

(*f*) *Industrial development.*—The Government should pursue a policy of vigorous encouragement to the development of a strong nucleonics industry. Isotopes isolated from the fission products of piles or directly produced by neutron bombardment in piles should be made commercially available. They will find applications as tracers in scientific and technological studies, as therapeutic agents in medicine, and as concentrated sources of radiation or energy for use in attacking special problems as in radiography, geophysical exploration, illumination, packaged power production, and other fields. Attention should be given to the direct use of radiation from active piles for medical treatment and for producing useful modifications in the structural properties of solids, or for inducing desirable chemical reactions.

The development of a strong nucleonics industry is regarded by the committee as a very important means of insuring national superiority in the new field. At the start such a development would require support from the Government which at present controls all raw materials, production plants, fissionable materials, and fission products. Moreover, the commercial applications already in sight are not sufficient to give assurance that a major nonmilitary industry could be developed in the immediate future. In the long-time future, however, growth of a self-supporting industry of great magnitude and many ramifications seems possible.

Dr. W. K. LEWIS,
Rear Adm. E. W. MILLS, USN,
Dr. H. D. SMYTH,
Dr. R. C. TOLMAN, *Chairman.*

APPENDIX TO SECTION 2, REPORT OF COMMITTEE ON POSTWAR POLICY

Persons who have presented views to committee

Name	Laboratory	Note	Name	Laboratory	Note
Abelson, Dr. P. H.	NRL	i	Kistiakowsky, Dr. C. B.	Los Alamos	m
Allison, Dr. S. K.	Chicago	i, m	Lawrence, Dr. E. O.	California	i
Alvarez, Dr. L. W.	Los Alamos	m	Leverett, Mr. M. C.	Chicago	i
Anderson, Dr. H. L.	Chicago	i	Morrison, Dr. P.	do	i
Bacher, Dr. R. F.	Los Alamos	m	Mulliken, Dr. R. S.	do	i, m
Bethe, Dr. H. A.	do	m	Nordheim, Dr. L. W.	do	i, m
Borst, Dr. L. B.	Chicago	m	Ohlinger, Dr. L.	do	i
Brobeck, Mr. W. M.	California	i, m	Oppenheimer, Dr. F.	California	i
Brown, Dr. H. S.	Chicago	m	Oppenheimer, Dr. J. R.	Los Alamos	i, m
Cohen, Dr. K. P.	Columbia	i, m	Parsons, Capt. W. S.	do	i, m
Cohn, Dr. W.	Chicago	i, m	Reynolds, Dr. W. B.	California	m
Compton, Dr. A. H.	do	i, m	Seaborg, Dr. G. T.	Chicago	i
Cooksey, Dr. D.	California	i, m	Segre, Dr. E.	Los Alamos	m
Cooper, Dr. C. M.	Chicago	i, m	Seitz, Dr. F.	Chicago	i
Coryell, Dr. C. D.	do	m	Slack, Dr. F. G.	Columbia	i
Creutz, Dr. E. C.	do	i	Smith, Dr. C. S.	Los Alamos	m
Crist, Dr. R. H.	Columbia	i	Snell, Dr. A. H.	Chicago	m
Curtis, Dr. H. J.	Chicago	m	Soodak, Dr. H.	do	m
Dempster, Dr. A. H.	do	i, m	Szilard, Dr. L.	do	i
Doan, Dr. R. L.	do	i, m	Taylor, Dr. H. S.	Columbia	i
Dunning, Dr. J. R.	Columbia	i	Teller, Dr. E.	Los Alamos	m
Elgin, Dr. J. C.	do	i	Urey, Dr. H. C.	Columbia	i, m
Emmett, Dr. P. H.	do	i	VanKeuren, Adm. A. H.	NRL	i
Fermi, Dr. E.	Los Alamos	m	Vernon, Dr. H. C.	Chicago	i
Frank, Dr. J.	Chicago	i	VonNeumann, Dr. J.	Los Alamos	m
Gibbs, Capt. R. H.	NRL	i	Weinberg, Dr. A. M.	Chicago	i
Gunn, Dr. R.	do	i	Whitaker, Dr. M. D.	do	i
Hilberry, Dr. N.	Chicago	i	Wilson, Dr. R. R.	Los Alamos	m
Hogness, Dr. T. R.	do	i	Wollan, Dr. E. O.	Chicago	m
Jenkins, Dr. F. A.	California	m	Young, Dr. A.	do	i
Johnson, Dr. W.	Chicago	i, m	Zinn, Dr. W. H.	do	i
Kennedy, Dr. J. W.	Los Alamos	m	Zirkle, Dr. R. E.	do	m
Kilpatrick, Dr. M.	Columbia	i	Wigner, Dr. E. P.	do	m

Key: i—interview; m—memorandum; "Chicago" includes the Metallurgical, Clinton, and Argonne Laboratories.

A total of 66 persons are listed above. Of these, 44 were interviewed and 37 submitted memoranda (15 were interviewed and presented memoranda).

3. ATOMIC POWER

By Eilene Galloway

Public Affairs Bulletin No. 44, The Library of Congress, Legislative Reference Service, 1946

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"*5. Peacetime Uses of Atomic Energy*

"Man's attention has been focused primarily on the destructive rather than the beneficent uses of atomic energy. The menace of the atomic bomb will continue to be uppermost until effective national and international controls have been devised. But the promise held for civilization by this new source of power should be as motivating as the fear of destruction which impels us to prevent future wars. The release of atomic energy was inevitable; the only choice was whether it would first be discovered by the Nazis or by the freedom-loving nations. Now that the possibilities of atomic energy are known, mankind is faced with the necessity of adjusting himself to the world as a community. [1. Compton, Arthur H., Introduction to *One World or None*, New York, McGraw-Hill, 1946, p. v.]

"The release of atomic energy has brought about a revolution not only in methods of warfare—'Man will not live the same again for this advance. I do not think you will soon see atomic automobiles, though you may soon see atomic rockets and atomic power plants. But the changes which will come are sure, and great, and beyond prediction. When science learned to control mechanical and thermal energy, we had the early nineteenth century maturing of the industrial way of life. When science learned control over electrical energy, we had the manifold changes which electricity has brought to daily life and to the structure of nations. When the chemists understood the nature of chemical energy, there was opened the way to new materials, to freedom from the restrictions of mine and farm, to the changes which chemistry is even today still bringing us. Now we have nuclear energy, based on a more profound insight into and control over the fundamental nature of matter itself. We have seen war change only 6 years after the key laboratory discovery in this realm. We physicists are professionals in change and in novelty. That new times will come is our firmest conclusion.' [2. Dr. Philip Morrison, Hearings before the Special Committee on Atomic Energy, U. S. Senate, 79th Cong., 1st sess., December 6, 1945: 242.]

"The possible uses of nuclear energy for peacetime purposes were foreseen at the time the atomic bomb was being developed. In 1944, Maj. General Leslie R. Groves appointed Dr. R. C. Tolman, Dean of the Graduate School of the California Institute of Technology, to be chairman of a committee to study and make recommendations regarding non-military uses of atomic energy. These uses lie in the field of power and in radioactive by-products for scientific, medical, and industrial purposes. There was agreement among the scientists that atomic energy would produce a great new industry, but disagreement as to the length of time it would take to develop the industry. The first consideration of this subject led to the conclusion that growth would be slow, with nuclear energy used for special purposes within ten years. It was recognized that radioactive materials would affect scientific research and the treatment of diseases. [3. Smyth, Henry De Wolf, *Atomic Energy for Military Purposes*, Princeton, N. J., Princeton University Press, 1945: 224–225] On March 14, 1946, General Groves announced that approval had been granted by higher officials to release information on the use of atomic energy for peacetime purposes provided it does not impair our national security. The Tolman committee recommended the type of organization which would be desirable for handling this problem. Consisting mainly of scientists, the organization will recommend what information is to be released according to the Tolman committee principles. [4. New York Times, March 15, 1946: 3]

"The questions of when and how we shall have peacetime production of atomic energy, and what impact this new development will make upon our society, are still in the stage of discussion. As Dr. Vannevar Bush said, 'The situation in which we are placed at the present time * * * is one of great potential importance, but one in which practical results will certainly not come immediately * * * It is evident that there can ultimately be applications to the production of power within the reasonably near future, but the matter has not as yet been studied sufficiently to indicate just how economical these may be in comparison with other sources of power.' [5. Hearings before the Committee on

Military Affairs, House of Representatives, 79th Cong., 1st sess., October 9, 1945: 34.] Dr. Bush anticipated that some results of a commercial nature might be expected in 10 years. [6. Ibid., p. 42.] General Groves agreed that commercial use could be expected in ten years. [7. Ibid., p. 18.] Dr. James Bryant Conant, President of Harvard University, thought development should be slow and gradual and that people should not get the impression that automobiles would be run on atomic energy within a couple of years. [8. Ibid., p. 56.] Dr. Leo Szilard testified '10 years from now atomic power could be a very important factor in our national economy.' [9. Ibid., p. 88.] Secretary of Commerce Henry A. Wallace was of the opinion that atomic energy could be harnessed within a year for peacetime purposes. Dr. Edward U. Condon, director of the National Bureau of Standards, thought that electricity could be produced from an atomic-powered test plant within a year. Such a testing plant could study the possibilities of general use of atomic energy for peacetime purposes. [10. *Washington Post*, March 3, 1946: 1.]

"Research into the subject of atomic energy may lead ultimately to ends not now foreseen, but at present two great fields for peaceful-development are envisaged: (1) the use of atomic energy as a controlled source to furnish heat and power; and (2) the application to science and the arts, particularly in medicine, chemistry, and physics.

"The problem of making nuclear energy available as a source of power was discussed by Dr. J. R. Oppenheimer, director of the Los Alamos Laboratory which developed the atomic bomb. 'The technological problem of operating (controlled nuclear chain reaction) units to produce energy at a temperature high enough to make it profitable to generate electrical power, or to provide steam for heat or for industrial uses, appears to be capable of solution in many ways in the very near future. We see no real limitation on the availability of nuclear fuel. Therefore, we may look confidently to the widespread application of such sources of power to the future economy and technology of the world.

"'One word of warning may be appropriate; a unit of this kind, operating, let us say, at a thousand kilowatts, produces radiations roughly equivalent to those from ten tons of radium. If men are to be anywhere around such units, this radiation must be absorbed by shields of very appreciable bulk. For this reason alone, we do not think automobiles and airplanes will be run by nuclear power units—not, at least, until a new idea supplements our present knowledge.

"'But the fact that nuclear-energy units require an insignificant amount of fuel makes us think that they will be applied to extend the present uses of power in our economy. We do not expect petroleum or coal to become outmoded as fuels. It is clear that although useful power plants may be only a few years away, the full adaptation of the new possibilities to a living economy will be a matter of many more years than that.' [11. Oppenheimer, J. R., "Expert Discusses International Use of Atomic Power", *Commercial and Financial Chronicle* (New York), December 27, 1945: 3133, 3145. Text of a radio address delivered on December 23, 1945.]

"The National Association of Manufacturers, holding its convention in New York during December 1945, brought together a panel of experts to discuss the peacetime uses of atomic energy. Dr. James B. Conant, President of Harvard University, acting as moderator of the symposium, asked how long it would take to develop an atomic power plant of 100,000 kilowatt capacity which could compete with $15 a ton coal? General Groves, having in mind the difficulty of engineering and construction problems as well as those of physics and chemistry, thought it would be a matter of decades, but Dr. Charles A. Thomas, vice-president of the Monsanto Chemical Company, thought it would be possible within a decade. Dr. J. A. Wheeler, Professor of Nuclear Physics at Princeton University, thought the task could be accomplished in three to ten years, an estimate with which Dr. Crawford H. Greenwalt of E. I. du Pont de Nemours Company, agreed. Other estimates varied from 15 to 25 years. [12. *New York Times*, December 7, 1945: 1, 4.]

"The conclusions of the panel discussion with reference to other questions were that the initial cost of atomic energy would be higher than that for power derived from coal, oil, or natural gas, and therefore the first uses would be specialized. Protection against radioactive rays requires a heavy plant construction of, say, 50 tons. This means that oceangoing vessels, or possibly locomotives, might be powered with atomic energy, but not automobiles. The engineering problem involved is to convert the heat generated by atomic fission into mechanical power. At the Hanford, Washington plant, designed to produce plutonium for use in atomic bombs, the heat was carried away by the Columbia

River as a waste product. The reverse would be true of peacetime development, with the heat used for power and plutonium regarded as a by-product. Mr. William L. Laurence, of the New York Times, brought out that atomic power is 3,000,000 times as powerful as that which we have been using for the last 500,000 years. We can no more visualize fully now the extent of peacetime application of atomic energy than those who discovered electricity could have foreseen its present-day uses. [13 *Newsweek*, December 17, 1945: 76.]

"Dr. John Ray Dunning, director of the division of research at Columbia University, pointed out that two pounds of uranium-235 equals 6,000,000 pounds of coal. Such power could be used for large stationary plants and transport units, possibly super-sized, jet-propelled aircraft, and rockets. He agreed with the opinion of other experts in regard to the unlikelihood that atomic energy would be used for motor vehicles because of the problem of protection against radiation. Dr. Dunning said that we had only 'scratched the surface' thus far, with the possibility in the future of producing other fissionable materials. [14. *New York Times*, January 8, 1946: 21.]

"Nuclear energy is extremely concentrated in form and will be advantageous to use where the weight and bulk of ordinary fuels is not advantageous. It would be possible to establish power plants in those parts of the world where it is not now economically sound to build up an industrial civilization on the basis of coal, oil, gas, or water power.

"In addition, a nuclear power plant produces new fuel as it burns up its fuel, making it possible to view the production of fissionable material as a byproduct of power, or vice versa. 'From this point of view the economics of nuclear power is rather more like the economics of water power than that of coal power. We often build dams for flood control, irrigation, soil conservation, and the like; the power which they produce is in these cases secondary. It is not too important whether the power would compete with coal power, the dams are built, anyway. Similarly, we shall build plutonium factories in which the power is a byproduct. These plants will, like dams, have a multiplicity of uses. They will produce plutonium for use in specialized power plants. They will produce radioactive materials for technology and medicine. They will yield facilities for scientific research.' An atomic authority with a complex of functions similar to those of the Tennessee Valley Authority, would 'most naturally be located in a region which is not endowed with water power and is not now served by private or public power. * * * I have outlined what to me appear reasonable lines of development for atomic power. There remains the question what can Congress do to create conditions in which the development will flourish.' We are low in trained personnel and do not have a control system which will permit normal development. [15. Weinberg, Alvin M., Hearings before the Special Committee on Atomic Energy, U. S. Senate, 79th Cong., 1st sess., December 12, 1945: 337, 338, 339.]

"The application of atomic energy to medical research is one of its chief peacetime uses. Artificial radioactivity, resulting from atom-smashing is a new tool for use in science and technology. Nuclear power releases an enormous quantity of radioactive substances. Hitherto, only small amounts have been available for research. Medical discoveries and new therapeutic techniques have been developed and made available during the last twelve years. '* * * through medical advances alone, atomic energy has already saved more lives than were snuffed out at Hiroshima and Nagasaki.' [16. Evans, Robey D., 'The Medical Uses of Atomic Energy,' *The Atlantic Monthly*, (Boston), January 1946: 68–73.]

"The cyclotron which produced the first plutonium for the atomic bomb is being converted for research on cancer and other medical problems. Pointing out that the chances for success were greater than before, Prof. Ernest O. Lawrence, of the University of California, stated: 'We are about to point the way toward the cure of certain kinds of cancer. That does not mean we will be able to cure all kinds of malignancy, but we hope that in a few years we can show significant percentages of success in the treatment of some varieties.' [17. *New York Times*, December 3, 1945: 3.]

"Radioactive carbon for use in research into living matter will now be available. Radioactive tracers have been used in biochemical research by physicians working in the physiology and pathology of plants and animals. Tracers enable the researcher to mark certain atoms so that they can be followed through the metabolic processes. Radioactive tracers were developed during the war to deal with the problem of preserving whole blood for at least twenty-one days so that it could be shipped by air to battle fronts. Future research studies may deal

with nutrition, the effect of drugs, anesthetics, the treatment of malignancies, and the transmission of diseases by insects. There will be need for adequate supplies of radioactive isotopes by laboratories so that industrial production of such materials will be stimulated. [18. Evans, Robley D., op. cit., p. 68–73.]

"High intensity radiation may also be applied to the field of industrial chemistry. 'Just as plants synthesize sugar under the influence of sunlight, so many other chemical reactions—some of considerable importance industrially—can be made to proceed in the intense radiation field of a chain reacting pile. * * * If man could duplicate this photosynthesis process (of manufacturing sugar out of carbon dioxide, water, and sunlight) first in the laboratory and then on an industrial scale, the bountifulness of the earth would be multiplied indefinitely. The world's fuel and food supply would be assured as long as the sun continues to emit light. The most powerful tool at the chemists' disposal for understanding, * * * is radioactive carbon, a byproduct of nuclear power. If, as a result of our greatly increased production of radioactive carbon the riddle of photosynthesis is solved, that, and not power plants or atomic bombs, will stand as the greatest achievement of nuclear power.' [19. Weinberg, Alvin M., Hearings before the Special Committee on Atomic Energy, U. S. Senate, 79th Cong., 1st sess., December 12, 1945: 335–336.]

"We know very little as yet about the peacetime uses of atomic energy, and until we know what the new inventions are, it is difficult to estimate their social effects. An analogy with the industrial revolution indicates, however, that many social changes may be expected. Steam made cities possible; indirectly shifted farming from subsistence to commercial patterns brought about a new economic organization, altered social classes, brought about a new distribution of wealth, and shifted the rank of nations in military power. Steam destroyed the household economy, affected the position of women, and brought 'problems of health, crime, education, divorce, recreation, morals, religion, justice. * * * It is only necessary to state that the evolution of the release of atomic fission bears watching and that there are factors which make it possible that the social effects will be many, radical, and profound. * * * it is possible that very cheap power might work out to increase greatly the standard of living. * * * The social changes due to the peacetime uses of atomic energy might become vastly greater than the social changes that may follow the bomb alone. * * * the study of institutions, custom, social behavior, and ideology has been nearly always a study of either of the past or of the present, which very quickly becomes the past. * * * But action in an age of social change should rest on considerations of the future.' [20. Ogburn, William Fielding, 'Sociology and the Atom', *The American Journal of Sociology*, (Chicago, Ill.), January 1946: 267–275.]

"Research and education for the future were the concern of President Roosevelt when he wrote Dr. Vannevar Bush, on November 17, 1944, asking the following questions:

"'(1) What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge?

"'(2) With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?

"'(3) What can the Government do now and in the future to aid research activities by public and private organizations?

"'(4) Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?' [21. Bush, Vannevar, *Endless Horizons*. Washington, D. C., Public Affairs Press, 1946, p. 39.]

"These questions, studied by advisory committees, led finally to a report by Dr. Bush on *Science—The Endless Frontier*, in which the proposal is made to create a National Research Foundation. [22. *Science—The Endless Frontier*, A Report to the President by Vannevar Bush, Washington, D. C., U. S. Govt. Ptg. Off., 1945. 184 p.] Dr. Bush's program is for science, but he points out that 'Progress in other fields, such as the social sciences and the humanities, is likewise important; * * *'

"Dr. William F. Ogburn holds that 'For every subsidized piece of research in natural science there should be corresponding financial aids to research in social science. Since two billion dollars were spent on making the atomic bomb

which will produce many social problems, an intelligent society would aid social research to solve the problems the bomb creates.' [23. Ogburn, William Fielding, 'Sociology and the Atom', *The American Journal of Sociology* (Chicago, Ill.), January 1946: 274.]

"The advance of science has brought mankind to the crossroads of social progress or the destruction of civilization. 'It still remains to be seen whether or not the new atom around us can destroy the old Adam within us—whether or not human nature can assimilate the age of alchemy and adapt itself to its implications, and man still survive not merely as a species but as a spirit. * * * "The atomic age is here to stay; but are we?"' [24. Jordan, Virgil, 'Frame of the Future for America', *American Affairs*, (New York), October 1945: 200.1.

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4. DEVELOPMENT OF ATOMIC POWER NO SIMPLE PROBLEM

(Released by Public Relations Office, Oak Ridge, Tenn.)

OAK RIDGE, TENN., November 21, 1946.—The complexities of the problem of generating electric power from atomic energy are indicated in a review published today of the status of the nuclear power development program of the Manhattan project.

The organization and general research program for the utilization of nuclear energy for the generation of electric power was outlined in a nontechnical report released to provide a basis for better understanding of the problems involved.

"This is not a report as we normally use the term," officials said. "It is merely a review of the background information, outlining the problems which confront the scientists and engineers working on this phase of our broad program. It indicates that progress is being made.

"We have no headline-making accomplishments to report, but the Manhattan project is carrying out an intensive research and development program. We are employing techniques of management developed during the war period, coordinating and concurrently pushing the scientific, engineering and operating planning of the work. We hope this information will be useful in providing a basis for a better understanding of the problems involved."

The status of the power project was described as follows:

Two prime contracts have been awarded for the development of power, one to Monsanto Chemical Co. of St. Louis, and one to the General Electric Co.

Monsanto Chemical Co., which operates the Clinton Laboratories at Oak Ridge, Tenn., for the Government, is working on a power pile based on preliminary designs and suggestions of Dr. Farrington Daniels, professor of chemistry at the University of Wisconsin and Chairman of the Board of Trustees of the Argonne National Laboratory, Chicago. Dr. Daniels is serving as a consultant to the Clinton Laboratories Power Pile Division which is headed by Dr. C. Rogers McCullough. The research and development program at Clinton Laboratories is under the supervision of Dr. E. P. Wigner. When the design has been prepared, it is contemplated that an experimental plant will be built at Oak Ridge.

Studies of power piles were begun by Dr. Daniels in 1944. The feasibility of the proposed pile was established shortly thereafter by theoretical calculations made by Dr. Daniels and his associates. Investigations of anticipated problems were then carried out at the Metallurgical Laboratory (now Argonne National Laboratory) in Chicago until 1946, when a committee, acting for Col. K. D. Nichols, district engineer, Manhattan district, reviewed the work which had been done and initiated the broad problem which is under way today. At the present time, the research work is divided between Clinton Laboratories under Dr. Wigner and the Argonne National Laboratory under Dr. W. H. Zinn.

General Electric Co., which now operates Hanford Engineer Works at Pasco, Wash., is working on several different designs of nuclear reactors, or piles, for the generation of electric power. No basic design has been agreed upon. The General Electric research program is under the direction of Dr. C. G. Suits and includes research on a wide range of equipment for nuclear power plants and the study of ship propulsion by nuclear energy. A Government-owned atomic power laboratory is scheduled to be built at Schenectady, N. Y., for this work.

The power pile program at Oak Ridge is now at the stage of putting together the preliminary design. Meanwhile, the problems which are being actively worked on are: the actual size and shape of the fuel unit, the method of transferring head from the pile to the heat engine or the prime mover, the problem

of loading and unloading the pile, the problem of automatic control of the pile and its accessory equipment, including steam turbine and generator and the problem of shielding the whole unit for protection against radiation.

"This pilot plant for nuclear power will be pushed to completion as rapidly as possible," said Dr. James H. Lum, director of Clinton Laboratories. "Numerous experiments must be made before final design can be settled. These experiments may well consume all of 1946 and part of 1947. The difficulties of procurement of equipment of this special category may also delay until 1948 the starting of the final pilot plant."

Considerable emphasis will be laid, during design and construction of the plant, upon achieving a heat source of long life and great reliability. These attributes are of particular importance because of the radioactivity which renders any pile, once operating, difficult and dangerous to shut down for maintenance. The radioactivity requires heavy shielding of the pile.

The pile's first operation will be to provide heat energy for steam-electric generation: operating at conventional control station temperature levels ranging from 650° F. to 940° F.

No indication may be had as yet of the capacity of the pilot plant. It is possible that all equipment will be relatively conventional from the boiler through the generator. None of the major components has as yet been ordered and their production would require months under normal circumstances.

The Monsanto Chemical Co. accepted the assignment for the experimental project at the specific request of the Manhattan project. In an effort to obtain the best talent and to give industrial concerns an opportunity to participate in the experiment, invitations to various companies and groups were issued by Monsanto as prime Government contractor. Engineers and scientists from the companies invited have been given leaves of absence from their firms, and assigned to the power project.

Representative groups affording working members to the power plant are:

Allis-Chalmers Co., Milwaukee, Wis.
Babcock & Wilcox Co., New York City
Bureau of Ships, United States Navy, Washington, D. C.
Fredric Flader, Inc., Tonawanda, N. Y.
General Electric Co., Schenectady, N. Y.
National Advisory Committee of Aeronautics, Washington, D. C.
Northrop Aircraft Corp., Hawthorne, Calif.
Tennessee Valley Authority, Knoxville, Tenn.
Purdue University, Lafayette, Ind.
Wright Aeronautical Corp., Woodbridge, N. J.
University of Wisconsin, Madison, Wis.
University of Chicago, Chicago, Ill.
Westinghouse, Pittsburgh, Pa.

Individuals and industrial companies who are performing consultant service with the Power Pile Division, are:

Dr. H. Colvin, Point Pleasant, N. J.
Dr. Farrington Daniels, University of Wisconsin, Madison
Combustion Engineering Co., New York City
Commonwealth Edison Co., Chicago
Foster Wheeler Corp., New York City
Fredric Flader, Inc., Tonawanda, N. Y.
General Electric Co., Schenectady, N. Y.
J. E. Willard, University of Wisconsin, Madison
J. I. Yellet, research director of Locomotive Development Committee (a research group sponsored by several railroads and coal companies)
National Carbon Co., Atlanta, Ga.
Consolidated Edison Co., New York City.

The problems will include turbines, blowers, condensers, heat transfer units and generators, and some of the companies participating are experts in these fields. The services of these experts will be utilized to the fullest extent. Basically, the present program is confined to a study of the over-all problem with each group joining in the various studies.

TECHNICAL PROBLEMS

In a consideration of the generation of electric power from atomic energy it is important to realize that atomic or nuclear energy does not involve entirely

new methods of power generation as did the steam engine; it is simply a new fuel and can be used only within the framework of present-day power generating systems. Although there is a remote possibility that in the future some of the energy available within the atom may be released directly through a medium other than a heat engine, such a device is not at present known. The current work is concentrated on the problem of adapting present power-producing techniques and equipment to this new type of fuel.

As matters stand, no element of a power plant can be omitted when nuclear energy is used to replace our present forms of fuel, although fuel handling equipment will be greatly reduced in size and may be omitted entirely in plants designed to operate for a limited time.

A great deal which has been written since August 6, 1945, has created the general impression that the solution to the problem of power generation from nuclear energy was achieved when the bomb was successfully tested. This has no basis in fact. A bomb and a power pile are two vastly different problems.

The bomb was a "one-shot" device. The objective in bomb development was an explosion, and the consequent destruction of the bomb. A stationary power pile, on the other hand, must be designed to last for many years. It must be capable of starting and stopping quickly, and of being controlled continuously, with precision, over a wide range. Furthermore, its design must incorporate features to prevent irradiation of personnel.

The designer of an atomic power pile has practically no data to guide him, so new is the field. He must feel his way without certainty of the correctness of his design until actual tests of the completed structure are conducted.

The difficulties in designing and constructing an atomic power plant can be broken down into four broad fields:

1. Materials of construction
2. Heat transfer medium
3. Auxiliary and operating equipment
4. Safety.

Concerning the first category, materials of construction, materials must be found which not only meet the requirements of present power production facilities, that is, possess strength, resistance to deformation and ability to withstand high temperature, but also have the additional quality of not breaking down under neutron bombardment. The metals used in a power pile must be capable of withstanding very high operating temperatures and considerable research and testing will be required to develop suitable metals.

A suitable moderator to slow the neutrons down to the desirable speed must be employed in some pile designs. Again, besides possessing the required neutron and moderating qualities, this material must be capable of operating continuously at high temperatures.

The second major field of difficulty which requires much research and investigation is the choice of a suitable heat transfer medium or pile coolant. The purpose of the coolant is to remove the heat generated by fission within the power pile and convey this heat energy to the power system. Theoretically, it is possible to use ordinary water, heavy water, gases, or liquids other than water. Several liquid metals are being studied, but little is known of their properties from a nuclear and corrosive standpoint.

The third broad field is the design and development of auxiliary and operating equipment such as pumps, blowers, valves, and heat exchangers. Since these may become radioactive during operation of the pile, they must be so designed as to be trouble-free and must require either no maintenance for extended periods of time, or maintenance by remote-control apparatus which entails obvious difficulties. Further, because of the danger to the personnel, the pumps, blowers, and valves must remain absolutely tight and prevent any leakage.

The protection of pile operators from radiation and radioactivity and other fission products is the fourth broad field of difficulty confronting the designer of an atomic power plant. The radioactivity emanating from a power pile is the equivalent of tons of radium. Much of this radioactivity persists even after the pile is shut down. For protection against the radiation it is necessary to use materials that are effective in slowing down or stopping neutrons and in absorbing gamma rays. At Hanford, where plutonium production piles are located, massive shields are necessary.

Thick shields are required even for piles producing a relatively small amount of power. At the present time this is a major difficulty retarding the development of small atomic power plants or nuclear reactors.

Besides these four broad fields of investigation, several long-range considerations must enter into any discussion of the generation of usable power from an atomic pile.

It is important to keep in mind that we do not at this time have sufficient knowledge or experience with nuclear fuels to make any predictions as to the future economic position of nuclear fuels with relation to conventional fuels.

COST FACTORS

A report on the cost estimates of nuclear power was recently made to the United States representative, Mr. Bernard M. Baruch, on the United Nations Atomic Energy Commission. The study was made by members of the staff of Clinton Laboratories at Oak Ridge and the Monsanto Chemical Co. engineering department under the direction of Dr. Charles A. Thomas, vice president and technical director of the Monsanto Chemical Co.

The report follows in part:

"While no such plant (nuclear power plant) has ever been built, it is felt probable that a large stationary nuclear power plant could be built. Based on prices now current, a plant designed along the lines indicated and producing 75,000 kilowatts could be built in a normal locality in the eastern United States for approximately $25,000,000. On the assumption that the plant would operate at 100 percent of capacity and that interest charges on the investment would be 3 percent, the operating cost of the plant would be approximately 0.8 cent per kilowatt-hour.

"This is to be compared with coal power plants which would cost $10,000,000 under the same conditions. The operating cost depends on the price of coal. The price of bituminous coal of 13,500 B. t. u. is about $3.50 per ton at the mine and about $7 per ton delivered to the furnaces of a power plant in the eastern United States. The operating cost of such a power plant would be approximately 0.65 cent per kilowatt-hour, again on the assumption that the plant would operate to 100 percent of capacity and that the interest charges on the investment would be 3 percent. Equality of operating costs between coal power plants and nuclear power plants would be reached if the coal cost $10 per ton. It must be realized that lower costs of nuclear power plants can best be achieved by continued research and development.

"It should be emphasized that these costs imply the successful solution of a number of difficult technological problems.

"In the case of nuclear power, the operating cost is greatly affected by the large investment, which is reflected in the interest, depreciation and maintenance charges. The labor and supervision charges for the nuclear plant are expected to be greater for the coal plant, until such time as the production of electrical power from nuclear energy has been further developed. It seems reasonable to expect that the future development of nuclear power will result in the standardization of design and construction, and a material reduction in the investment and operating cost.

"The cost of power from coal is primarily determined by the price of coal, which constitutes about 55 percent of the total operating cost. The prices of coal and fuel oil have increased greatly since before the war and show signs of increasing further in the future. The coal plant figures are based on high quality coal as delivered to plants in the eastern part of the United States during the second half of 1946. It would appear that the cost of nuclear power may decrease and the cost of coal power may increase as time goes by, and that the development of nuclear power may prove to be attractive to those industries which are capable of undertaking the development.

"Nuclear power plants would make feasible a greater decentralization of industry, a desirable factor in the world economy. Only a trivial amount of fuel need be brought in, and the need for a large cooling water supply might be obviated by the development of gas turbines.

"Nuclear power plants in contradistinction to hydroelectric power plants have the advantage of being able to supply process and heating steam directly in addition to power. Because nuclear plants lend themselves to decentralization, more economical industrial combinations should develop.

"Research has already shown possibilities for use of radioactive isotopes in analytical work and medical treatment. These isotopes would be valuable by-products from the production of power, although they would probably have little effect on the economics of power generation.

"The nuclear power plant might aid in the industrial development of isolated parts of the world where the cost of oil, gas or coal is prohibitive and where a

suitable water supply is unavailable, because the nuclear power plant, if combined with the modern gas turbine, would make unnecessary a supply of any such fuels or cooling water.

"The nuclear power plant, in connection with the modern gas turbine, might be desirable as operating or stand-by plants to existing large utilities.

"On the basis of this study, and other similar studies which have been made recently, it seems probable that nuclear power will find favorable industrial application if obstacles are not placed in the path of its development.

"It is not altogether a case of nuclear power versus coal, oil or water power, because the nuclear power plant has advantages and fields of application not open to other types of power producing plants."

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5. AIRCRAFT AND NUCLEAR PROPULSION SEMINAR

(Released by Public Relations Office, Atomic Energy Commission, Oak Ridge, Tenn.)

OAK RIDGE, TENN., February 6, 1947.—A seminar on nuclear physics with special emphasis on the application of nuclear energy to aircraft was under way at Oak Ridge today. The sessions will continue through February 12.

The seminar is part of a joint industry-government program for research and development in the field of nuclear energy for the propulsion of aircraft which was inaugurated recently with the establishment of a special staff group at Oak Ridge.

The program for study of nuclear energy for the propulsion of aircraft, known as the NEPA project, is a combined operation of 10 aviation companies and the National Advisory Committee on Aeronautics, working with the Fairchild Engine & Airplane Corp. as prime contractor under the Army Air Forces.

Persons attending the seminar include high Air Force officers, officials of the Fairchild Engine & Airplane Corp., among them J. Carlton Ward, Jr., president, and representatives of the 10 companies participating in the program.

Information developed by the NEPA will be made available to the Navy through liaison with the Office of the Assistant Chief for Research and Development, Navy Bureau of Aeronautics.

The NEPA Technical Staff at Oak Ridge, as one of the first steps in getting the research project under way has established working relations with Monsanto Chemical Co., which operates Clinton Laboratories at Oak Ridge for the Government, and has investigated technical and scientific information obtained previously on the Manhattan Project for selection of pertinent data for study. Close coordination is being maintained with the Monsanto Chemical Co. in view of the work now being carried on by that company in design of a pilot plant for experiments in the generation of electric power from atomic energy.

Calculations in the applications of nuclear energy to various types of aircraft power-plants have been carried out and the ground work has been laid for the design of aircraft-type nuclear reactors, although design work has *not* actually been placed on the drawing board.

Work on three research projects directly pertinent to aircraft application of nuclear energy, all of which have been initiated by NEPA, has been started at the National Advisory Committee for Aeronautics at Cleveland, Ohio, at the Massachusetts Institute of Technology and at Fredric Flader, Inc., Tonawanda, N. Y. A number of other research projects are being prepared, among them one at the Burbank plant of the Northrup Aviation Corp.

With the first stages of the development under way, a physical-chemistry and electronics laboratory in the NEPA area at Oak Ridge is being installed and is expected to begin operation very shortly.

In releasing information on the present status of the program, all NEPA officials at Oak Ridge emphasized that the project is a long-range one and that many months will pass before tangible results can be achieved in research.

The officials also emphasized that due to the fact that a considerable portion of the research work will be subcontracted elsewhere, the number of persons employed at Oak Ridge by NEPA will be relatively small. Employment in general at Oak Ridge, it was said, will be limited to persons of highly technical or scientific background.

Air Forces officer in charge of the NEPA project at Oak Ridge is Maj. Donald J. Grant, a representative of the Air Matériel Command, who is coordinating

the NEPA research program with the Air Force's projects at Wright Field and with the Office, Chief of Research and Engine Division, Headquarters, Army Air Forces, Washington. Prior to his assignment at Oak Ridge, Major Grant was Army Air Force plant representative for Fairchild Engine Corp. at the Fairchild Aircraft Division at Hagerstown, Md. Before that, he was Assistant Director of Defense, Headquarters, Fourth Air Force, San Francisco.

Technical Director of the NEPA project at Oak Ridge is Gordon Simmons, Jr., former chief mechanical engineer for the J. A. Jones Construction Co. during the building of the gaseous diffusion plant for concentrating U–235 at Oak Ridge. Mr. Simmons is working closely on the NEPA project with J. Carlton Ward, Jr., president of Fairchild, J. A. Armitage, formerly connected with Carbide & Carbon Chemicals Corp. at Oak Ridge, is in charge of the NEPA administrative phase.

Chief engineer of NEPA is Andrew Kalitinsky, who was connected with Pratt & Whitney prior to serving as a lieutenant with the Navy Bureau of Aeronautics.

Major Grant, as officer in charge of the project, had high praise in a statement for the cooperation of the Manhattan District in aiding in coordinating the work incident to the establishment of the project and in facilitating the program and expressed appreciation for "the very fine assistance which had been given by the District."

The NEPA program is directed by Maj. Gen. Curtis LeMay, Deputy Chief of Air Staff for Research and Development.

The NEPA project will comprise investigation of the applications of nuclear energy to all possible systems of propulsion of aircraft. It will include a study of closed-cycle turbines, open-cycle turbines, turbo-jets, ram jets, and rocket devices.

The field of nuclear science is so new, and the problems of aircraft propulsion by nuclear energy so complex, that it will be some time before any major accomplishments can be reported. The program is well underway, however, and basic research is being undertaken covering the fundamental nuclear, thermodynamic, metallurgical, and ceramics problems.

The following companies, all active in the field of aircraft power plants, are cooperating with Fairchild in the project:

Allison Division of General Motors, Indianapolis
Continental Motors Corp., Detroit, Mich.
Frederic Flader, Inc., Tonawanda, N. Y.
Lycoming Division of Aviation Corp., Williamsport, Pa.
Menasco Manufacturing Co., Burbank, Calif.
Northrup Aircraft, Inc., Hawthorne, Calif.
United Aircraft Corp., East Hartford, Conn.
Westinghouse Electric Corp., Philadelphia, Pa.
Wright Aeronautical Corp., Woodridge, N. J.

In addition to the scientific and engineering staffs of the participating companies, a staff of special consultants have been engaged, including:

Dr. H. A. Bethe, Cornell University
Prof. C. R. Soderberg and Prof. W. H. McAdams, MIT
Dr. Morris Kolodney, City College, New York
Dr. H. H. Goldsmith, Argonne National Laboratories, Chicago
K. A. Browne, Chesapeake & Ohio Railroad
W. C. Rockefeller, A. P. Adams Associates, Los Angeles.

Services of other consultants will be obtained as the need arises, and other industrial organizations may be invited to participate as the program develops.

Dr. R. F. Bacher, formerly a consultant on the project with Fairchild, is now a member of the United States Atomic Energy Commission.

(From: AEC Press Release, February 20, 1947)

6. ARGONNE NATIONAL LABORATORY TO ACQUIRE PERMANENT SITE IN DU PAGE COUNTY

Acquisition of 3,645 acres of land in Du Page County, for the location of new permanent facilities of the Argonne National Laboratory for research and development in the field of atomic energy, has been approved by the United States.

Atomic Energy Commission, Dr. Farrington Daniels, Chairman of the Board of Governors of Argonne National Laboratory, announced today.

The new site, which is entirely within Du Page County, lies in an area bounded on the north by U. S. Route 66, on the east by Illinois State Route 83, on the west by Lemont Road, and on the south by the Atchison, Topeka and Santa Fe right-of-way (see attached map). The site is approximately 26 miles southwest of the center of Chicago, and is about 4 miles west of the location of facilities of the Laboratory in the Palos Area of Cook County Forest Preserve.

Present plans call for the immediate occupation of about 450 acres in the approximate center of the area, and for acquisition of the remainder of the land as rapidly as possible. Construction as now planned will begin as soon as weather conditions permit.

"The acquisition of a permanent site for new facilities of the Argonne National Laboratory," Dr. Walter H. Zinn, Director of the Argonne National Laboratory, said, "will ensure the Atomic Energy Commission, and the people of the United States a strong center in the Midwest for the development of atomic energy. This Laboratory has been established to engage in research and development in all phases of atomic energy, including fundamental research in the sciences of physics, chemistry, biology, medicine and engineering; the development of industrial power, and research on the military uses.

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7. ADDRESS GIVEN BEFORE THE ASSOCIATION OF EDISON ILLUMINATING COMPANIES, DETROIT, MICH., APRIL 18, 1947, BY CARROLL L. WILSON, GENERAL MANAGER, UNITED STATES ATOMIC ENERGY COMMISSION

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The resource of the United States which exceeds that of any other nation is its industrial might. As was so evident during the war, the imagination, the resourcefulness, the driving energy and courage of American industry, when brought to bear upon the problem of creating the greatest array of armaments in history, proved itself capable of doing the impossible and doing it quickly. In the atomic energy development during the war a multitude of American firms contributed their skills, energy, and organizational ability to the building of the enormous and novel plants which we now have. This is a dynamic field and the rate of obsolescence is high and the installations are big. If we are to make progress in the development of atomic energy for the future, many ways must be found which are proper for the Commission and will be attractive to American industry to stimulate vigorous participation in this great undertaking.

When the day comes when we have a power reactor capable of generating useful power economically, it will consist of a great many components. It will be very much more complicated than any present-day boiler. It will include the reactor itself, made of special materials; there will be a number of auxiliaries such as pumps, seals, blowers, valves, coolants, heat exchangers, and a great array of instruments for accurate control. It will be housed in buildings of special design and include associated chemical separation and recovery equipment. There will be numerous safety devices to insure the safe control and operation of the reactor. And all of these parts, as well as the design and building of this assembly, should be done by industry. And there should be enough firms with the "know-how" and capacity to produce these various components so that there will be a lively competition among them to produce the best and cheapest heat exchanger, blower, pump, meter, or other part. And in developing components for these purposes other uses are certain to be found for many of them. In the whole field of new materials upon which successful design and construction of power reactors depend in such large measure—new alloys, ceramics, and other materials will be developed which will have many other useful applications in industry.

In the field of research and development we must bring about a very wide participation by many institutions in advancing knowledge in this field—a field in which we are continually bumping up against the frontiers of scientific knowledge. Similarly, in the development, design, construction, and operation of the reactors of the future there must be a wide participation by American industry.

Only if this enterprise is one in which broad segments of the whole American economy participate will it be possible soundly and quickly to go forward toward the realization of the great potentialities which this must hold.

Much experimentation is involved in discovering ways in which these many groups may be brought into a solid participation in this enterprise. Some of the hurdles are clear—such as that growing out of security restrictions. The way is largely unchartered, and mistakes will be made, but unless we go forward and try many new administrative devices with full knowledge that some will fail and some will bring criticism, this enterprise will be mediocre and fall tragically short of the expectations and requirements of the American people.

The Atomic Energy Commission will need the interested support and cooperation of a great many groups in devising ways in which it can fulfill the enormous responsibilities placed on its shoulders. It will need the constructive suggestions and ideas of people in many different pursuits, for there is no book of answers to the problems which must be answered.

A good deal of the momentum which the atomic energy program had in the summer of 1945 has been lost. Much of this was inevitable with the general relaxation which followed the end of the war. Nearly 2 years have elapsed since Hiroshima. During that time the Congress, after long and searching debate, framed the Atomic Energy Act of 1946. The Commission was appointed last October 28. It took over responsibility and control of the Manhattan project on January 1, 1947. The appointments made by the President have now been confirmed by the Senate. There is much to do in shaping the program in relation to national needs, in giving the enterprise a firm sense of direction and urgency, and creating as rapidly as possible a pattern of operation suited to effective and rapid growth in a peacetime environment.

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8. FUNCTIONS OF THE INTERNATIONAL AGENCY IN RELATION TO RESEARCH AND DEVELOPMENTAL ACTIVITIES

Statement by Dr. J. Robert Oppenheimer, Professor of Physics, the California Institute of Technology and the University of California, on April 29, 1947, at the Seventeenth Meeting of Committee 2

(Released by Office of United States Representative, United Nations Atomic Energy Commission, Empire State Building, New York, N. Y.)

I have not met with this Committee for a long time, and I am quite sure that such usefulness as my coming here can have to you will derive mostly from informal discussion and from my trying to answer questions that you may want to put.

I have read the seven working papers and, by and large, have been very much impressed, not only with the very great elements of agreement, but also with the clarity which permeates them. I think this is in some ways a good augury. I think that the problems of research and development are among those where the attack should be most clear and where agreement should be least difficult. But I should like to give you a little chance to think up questions, by talking about the problems of research and development, perhaps in a slightly new way, in a way that I hope may give a kind of depth of focus which is missing when one just looks at lists of problems. There is a certain tendency to list the problems that occur in this field without making the distinctions of time scale, of urgency, of importance, of difficulty which in reality will determine what the future will be like, what kind of progress is possible, and what kind of organizational arrangements are most suitable.

I think everyone has had the experience, when he first inquired into atomic energy, of being rather disappointed that the so-called benign uses, the so-called peaceful uses, seemed so extremely vague and so conjectural, and in some cases so remote, compared to the very immediate application in the form of atomic weapons. The reason for this is that, to an extent that is hard to overstate, the peaceful uses of atomic energy are a problem of research and development. They are this for more than one reason, as I will try to make clear. They are partly a problem of research and development because we do not know how to do things that we know we want to do. They are partly a problem of research and

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development because of the usefulness of the release of atomic energy in providing tools for such research and development.

Therefore, it need hardly be emphasized that any attempt to outline what the consequences of such research will be is most misleading, unless it is coupled with a statement that we do not know what the consequences of such research will be. What we have today are certain avenues which any prudent and imaginative group of men would wish to follow: But, before these avenues are explored, they will lead us to places which one cannot see. I stress this very strongly because in any administrative arrangements which are made for cultivating research and development, the notion of flexibility—of not prescribing in advance precisely the contours of the problems—must be very deeply and organically imbedded.

I would start then by an account of what to me are the visible areas of development, and I will try to give some feeling as to whether they are things which will pay off—which will lead to benefits—in a month or a year or a century. Having done that, I will speak a little of responsibility, of the organic relation which international agencies might appropriately have to these varied fields. In this, I am going to adopt the fundamental principle of *international cooperative development* of atomic energy. This is a controversial principle which has been argued about, but it seems to me that there has been sufficient agreement on it to warrant pursuing it in this discussion.

I would then like to say a few words about the scale of this activity. Will it take a thousand laboratories and a million people or will it take 2 laboratories and 10 people? I will make some general remarks about the prognosis for successful development, because I think this is a point which has not been stressed enough. I think, that is, that the advantages, the affirmative advantages of cooperative development, have perhaps been lost sight of in the very proper preoccupation with the elimination of atomic war.

I have listed six fields of investigation—others would make slightly different lists. The first is essentially the use of atomic energy as an instrument of research and development itself. As you know, this field was opened up before the war. The field would be a rich and valuable one if fission had never occurred and could never occur. The role of atomic energy, in its purely narrow and technical sense of the chain reaction, in making the use of tracers possible, is a limited but very important one. It is limited, because you can make both stable and radioactive tracers by other methods. What the development of reactors has done is essentially to give a limitless supply. In some cases this supply is undigestible. A fission product is manufactured normally in quantities far beyond any that seem to have usefulness in academic or industrial research. I have no doubt that uses will be found; but it is hard to handle hundreds of thousands of curies of material, and it is not clear to me that this will be a great thing for the future.

It *is* clear that in the case of tracers which are hard to make, where the yield is small, and of which the most notable and probably the most famous example is carbon 14, the availability of these tracers has quiet revolutionized the scale of activity. Only last week in Berkeley, Professor Calvin told me of studies that he has made on the dark reaction which precedes photosynthesis, in this case, in chlorella; and, by using some millicuries of radioactive carbon 14, he has been able to lay the groundwork for the identification of this material, this percursor to photosynthesis, which is a material of very low molecular weight and which presumably should lend itself readily to synthesis. This may mean profound alternations in our whole way of life. I need not point that out to a technical group. I mention this because, in the first place, it has happened. It is not something in the future. In the second place, it is characteristically incomplete and that will be true for a long time of all such researches. In the third place, it is one of the few things which really requires a reactor, because the quantity of radioactive carbon which he used would probably have been prohibitive without one.

This is characteristic also of the direct use of radiation which is again not a new thing. Gamma rays and neutrons have been used for allegedly therapeutic purposes for a long time, and some thoughts about their industrial use have occurred to people in the past; but here again the scale has been vastly increased by reactors. These are things which can start paying off in scientific insight, and probably in technical progress, very rapidly. They have started; and it is, of course, our earnest desire that these benefits be as widespread as they possibly can be. They are also applications which do not appear dangerous in the technical sense in which this word is used among us; that is, they do not form

any kind of a stepping stone on the way to atomic armament. They seem to be continuing uses just as the use of the microscope is. No doubt there was extraordinary excitement—in fact you can read in the history that there was—when the first successful magnifying glasses were made; but microscopes are still useful today. In the same sense, the tracer materials—stable and radioactive isotopes—and radiations used as a probe of the structure of matter, living and dead, are things which will become only more important as time goes on and as people learn more how to use them.

The actual development which is involved here is not entirely trivial because, for instance, before you can use radioactive carbon, you must find a suitable material to bombard in a reactor to make it, and, too, you may have certain problems of the chemical preparation of the material in order to learn all that is possible about it. For instance, you may want to put it in a certain carboxyl group in a bit of organic matter, in order to study rates of exchange. These are bits of research which are, in the first place, not very close to atomic energy, and, in the second place, are characteristic of the subject for which the tracers are to be used.

As for other uses, in physical research, of intense beams of neutrons, I may point out that the very precise measurements of the magnetic moment of the neutron were in fact accomplished using a reactor and that it is doubtful whether a comparably good job could have been done in any other way.

With regard to power, the other great development to which people who try to promote the benign uses of atomic energy usually refer, the situation is different in all respects. This is not a small-scale undertaking. It is not an undertaking which is likely to be successful if left to the random efforts of small laboratories. The time scale for it, though controversial, is certainly different from the time scale for the applications of radioactive materials. There are a number of problems which in fact are closely related. There is the problem of operating reactors at temperatures sufficiently high, so that significant power can be produced. This is a complicated problem in chemical engineering, complicated by what radiation does to materials, complicated by questions of heat transfer. I know little enough of the problem, but I do know that it is not primarily one in nuclear physics. It is primarily one of almost a new kind of engineering. This problem was not pursued by us during the war; we do not have a small generator of atomic power turning over a turbogenerator to demonstrate. My own view is that it should not be a matter of many years before delivering atomic energy in the form of electrical energy will be a proven thing. There will be some place in this country, and perhaps elsewhere, where you can go and see some kilowatts coming off a power line and reassure yourselves that the origin of these kilowatts was in the fission of fissionable materials, of nuclear fuel. But that is of course a very small part of the problem. In order to consider using power reactors, let us say, for specialized purposes, such as propulsion, and a fortiori for general power production, so as to relieve power shortages and to supplement power on the *present scale of world consumption*, you have to worry about the problem of fuel; and the problem of fuel is very largely the problem of making what in the terminology of these committees is called nuclear fuel. This does not happen overnight. This is something where one can erect from the fundamental constants, Planck's constant, the charge on the electron, and so on, a certain time scale which it will take to produce reasonable quantities of this fuel.

Therefore, speaking just as a guess, I would give the following estimate of three stages in the development of atomic power, and I assure you that this is not secret information, because there is no secret information as to estimating what the future holds in store.

I think that within 5 years, and possibly considerably less than that, there will be a demonstration of usable electrical energy derived from nuclear reactors. I think in a decade from now, and certainly in less than two decades, it may be possible to apply nuclear energy to certain specific highly critical problems of energy generation. Whether this will be to establish a station near the North Pole, or to propel ships or rockets, I don't know; but it will be a case where cost is not important, where one is willing to divert quite valuable material to a specialized and important objective. I think that it will take between 30 and 50 years before atomic energy can in any substantial way supplement the general power resources of the world. That is under the assumption that development is pushed, that intelligent and resourceful people work on the job, that money is available for it. That merely takes into account the very large number of things which have to be done before this program makes economic and technical sense.

In this connection, the second part of the power program is to get the fuels that you need. The problem is not merely to have high temperature power, but to accumulate and conserve the necessary fuels, all of which are derived from these primary raw materials of which we have spoken so much. In a reasonable system, the getting of power and the conservation of production of fuel should be concurrent characteristics of the reactors which are built. This is not a simple problem, and I think that it will take time, even from the point of view of finding out how to solve it.

The third area of development is the area of raw materials. This is not at all my field; but, from discussion with those who are experts in this field, there are two really rather great problems which would confront any agency, whether national or international. One is to find rational methods of discovering deposits. By this I mean both more incisive techniques for finding out that there is uranium in a certain place and better theoretical insight into the actual occurence of these materials in the surface of the earth. I know that it is easy to make wrong theories; but I will not believe that the application of human intelligence to this problem will leave one completely unprepared as to where one will and where one will not find significant deposits.

The second problem is surely a long-term problem, and that is the development of methods of recovery from ores now considered unworkable, that is, of such low grades that they are unworkable. Here again I would say these are efforts which will hardly prosper if left to the random enthusiasm of interested scientists. They probably require a developmental approach and a considerable degree of deliberate planned effort.

There are three other areas of activity that I have written down. One is the question of the origins of nuclear energy. I think there is a rather widespread belief that the pursuit of fundamental physics is related to atomic energy. It is in fact so related, but much less directly and much less foreseeably, I think, than is commonly assumed.

I may illustrate, for the scientists among us, the nature of the relation, by saying that I think the study of fundamental particles, nuclear forces, the reasons for nuclear stability, the properties of nuclear reactions, and so on, that these things, insofar as they relate to the future, bear to atomic energy about the same relation that the quantum theory does to organic chemistry. This theory is necessary, in order really to understand organic chemistry in terms of physics, but is not necessary in order to have a mastery of organic chemistry quite adequate for the manufacture of TNT and quite adequate for the study of plastics.

These studies of fundamental physics, which are extremely popular among my colleagues in this country, and no doubt abroad, are characteristically things which are conducted in universities, though sometimes in industrial laboratories, and which could be conducted in scientific institutes. They are, as I think was observed in the working paper of the United Kingdom, ideal training grounds for scientists. They correspond to an extension of the frontiers of human knowledge. They may lead, in some way or other, to practical consequences of immense import for the world; that they have a direct bearing on atomic energy is admittedly possible, but I should not predict that it is likely. I do not, in other words, believe in the cosmic-ray bombs of which we have read so much in the newspapers.

Here again these are activities which are now going on, which will continue and of which it is reasonable to expect that they will not be exhausted, at least in our lifetime, and where the prediction of any kind of practical fruit is really beyond even my indiscretion.

There are two other areas. One is the field of atomic explosives. Here I would like to separate a part of this field, which has some place in a peaceful world, and leave behind a part of it which has no place in a peaceful world. I think that the design of instruments for the delivery of atomic weapons, instruments for the fusing of atomic weapons, of minor improvements in the economy of such weapons, in the way in which they use the material, and so on, these are things which it is hardly reasonable to have studied, except with warlike intent. I think that the discovery of the possibilities of making atomic explosions, what kind of materials can be used, what principles of assembly can be used, what really goes on in an atomic explosion, these are matters which may need to be studied even in a peaceful world. I believe that very affirmatively, because I think that we do not too fully understand what the limitations and what the possibilities are, and I do not think it is possible to feel confidence in a system

of security which leaves unanswered questions which are capable of answer by the proven methods of physical experimentation.

There may be one other argument in favor of such study; it is conceivable—you have all heard it discussed—that atomic explosives may come to be useful for nondestructive purposes. Of course, physically they will always destroy something but they may be used for purposes which are beneficial, such as certain blasting operations or operations for the control of weather, and so on. I do not believe this is a very hopeful avenue of attack, but I do not think that, in any plans for the future, the door should be firmly bolted against exploring these things.

This brings me to a class of problems which unlike those I have discussed before exist by virtue of the notion—not the notion, alas, but the reality—of international control. These are researches which are directed toward purposes of control and safety.

I want here to mention parenthetically another matter. Anyone working in the field of atomic energy must make studies of the precautions that need to be taken to protect personnel against the hazards of radiation. But this goes without saying. It is not what I mean by researches directed toward safety.

In order to illustrate, let me give three or four examples. An agency which is worried about the destructive uses of atomic energy will be concerned to see to what extent use can be made of denaturants. This is quite a complex problem, even the outlines of which I cannot go into here. I can honestly say that I do not know, and, to the best of my knowledge, none of my colleagues in this country know, how useful denaturants will be—within the rather wide limits of the assertion that they will be of some use, and the certainty that they cannot be all-comprehensive as a scheme of control.

I will give a second example. Everyone knows that in the sun the reactions of light nuclei, notably of hydrogen, give rise to the energy that we live by. Every month or so a man will come around with some scheme for making this energy available terrestrially. The schemes I have heard are unsound. They will not work. But there is no law of nature that says you cannot make atomic energy on earth out of light nuclei. Therefore, it is necessary to keep open an avenue whereby any sound scheme that is proposed, or any scheme which is not on paper proven unsound, could be explored.

There are other things which tend toward the maintenance of safety. For instance, it has often been suggested that clandestine plants of a certain kind could be detected by the radioactivity that they emit. That wants to be explored. One would want to know whether there are simple methods by which the detonation of an atomic bomb in a remote area can reliably be detected. These are things which any agency that was really worried about maintaining security would want to be free to act upon. It would wish to explore any good suggestions that were made.

This is a sort of list of the fields of activity in research and development and some evaluation of how they fit in, which I thought worth sketching. I would be glad to pause at this point, if you wish to discuss these things, or equally glad to go on to the more organizational questions of the relations of an international agency to these problems. * * *

I am fully aware that almost everything I have said is quite familiar, but that is only a tribute to the thoroughness with which members of this committee have worked at the problem; and I am very glad it is so. I am glad there is very little that I can add that is new.

It has seemed to me that it would be useful—and here I think my views follow very closely the suggestions in the working paper presented by France—to distinguish three rather different kinds of responsibility that an international agency would have with regard to these activities. The first of these is what might be called primary responsibility, without which, in any undertaking, the agency could not do the other duties with which it was entrusted. The second is facilitative responsibility—a responsibility which was unique to the international agency, because it possessed the only facilities which made such work possible. The third responsibility is a secondary and benevolent responsibility, because on the whole it was a very good thing to have this work go on, the agency has an interest in it, but does not live and die by it.

I think these distinctions will become clearer by example. With the exception of its responsibility for control, the only thing which an agency dedicated to international development of atomic energy has to do now lies in the field of research and development. That is an overstatement. It does have to do some other things. It has to mine some uranium, look into the future, and so on; but

the peaceful uses of atomic energy are coextensive with research and development. Therefore, if one takes these words with the kind of seriousness that the situation warrants, I would say that the international agency would have a primary responsibility for the development of reactors, for the methods of producing nuclear fuels. Here my own view would be that, in the long term, the reactors themselves would be the most effective instruments for doing this, but that separation plants would play a necessary, if not major, part. The agency would have such responsibility for the discovery, exploitation, and recovery of raw materials, for the problems that I mentioned above, having to do with safety and with devices that can be used to render more or less likely the diversion of material to destructive ends, and for an understanding of atomic explosives.

When I say "primary responsibility," I do not mean by that that the international agency should forbid others to participate in this work. We will talk of that briefly later. But it should see that the work gets done and should by all means directly engage in the work, in laboratories of its own. Such laboratories are going to be large undertakings. They are going to be patterned after the typical wartime laboratory, which was mostly a place where development was carried out. They are going to be not too dissimilar from what in this country is a rather common pattern of industrial laboratory. They are not going to be very much like the academic laboratory in which fundamental physics, chemistry, and biology have in the past been pursued.

Quite different is the style of the facility laboratory, the laboratory which is built and perhaps operated by the agency but with the purpose of being useful to people outside the agency and with the purpose of making available facilities and techniques developed by the agency. A small reactor is in this category. Here I would not wish to insist that it be operated by the agency. That does not seem to me to be terribly important. It must at least be licensed, and it needs to be brought into existence by the agency. The agency must be responsible for seeing that such facilities are available where there are people to make use of them. Here a very much greater degree of dispersion is probably desirable. Here the pattern should probably be laboratories of quite moderate size and not very programatic; that is, anyone who comes in and says "I want to radiate this" should get permission, provided "this" is not something that will blow the place up and provided he is a competent scientist. These laboratories should be free laboratories in which the agency's great role is that it can facilitate the pursuit of scientific and technical matters.

In the third category, by way of example, I think it might be very desirable for the international agency to have a great synchrotron or synchrocyclotron. In fact, I would feel that it was quite wrong if it did not have a laboratory of that kind, partly because it would be out of style, partly because the discoveries made with that instrument might turn out to be of great importance. However, his is certainly a field in which it does not have a primary involvement. This is a great field in which men and women work in a rather badly organized manner, as scientists usually do, in institutes and universities; men and women who get up late and do not quite know what they are going to do tomorrow unless they do have a bright idea, in which they will work as they have in the past and from which essentially unpredictable findings about the natural world will emerge.

That goes for physics; it goes for chemistry; it goes for biology; and it goes for all those fields which have contact with atomic energy but in which that contact is only a very small part of the field. Atomic energy is a small part of science; it is only a very big problem in the contemporary world.

As was mentioned in the memorandum of the United Kingdom, I share the view that these three kinds of activities probably should not be mixed to too great an extent. What you run into when you mix developmental activities, which are programed, planned, and focused, with activities which are of an inquiring and scientific nature, is the rivalry of two incompatible snobisms. The scientist is irritated by the practical preoccupations of the man concerned with development, and the man concerned with development thinks that the scientist is lazy and of no account and is not doing a real job anyway. Therefore, the laboratory very soon gets to be all one thing or all the other. I remember that Dr. Fermi came to Los Alamos sometime after the foundation of the laboratory. He was somewhat horrified when he came to me and said, "The people here are actually interested in developing atomic weapons." That indicated the triumph of the engineer's view over that of the scientist.

Of all these things, there are to my way of thinking, only three where I would feel that a provision for monopoly by the international agency, as opposed to

the privilege to pursue and instruction to pursue, might appropriately be written into the paper setting up the agency. Two are in the fields of atomic energy explosives and in those parts of reactor development which use a large amount of explosive or potentially explosive material. My belief is that the reactor development of the future will involve large amounts of nuclear fuel, amounts so large that their diversion would in itself constitute a military menace, perhaps not a major menace but a disgraceful menace.

These two things and a third, which I would add as a possibility but not a mandate, would be the only fields of monopoly. As everyone knows, the third is that fission products can be used as poisons. I do not know whether this is a very effective form of warfare. However, the exploration of the potentialities here might well be left an international monopoly. Certainly it is something which should not be facilitated by the international agency as a national activity. One would not want the international agency to say, "Here are a million curies of radio-barium. See how many people you can poison with it." That would not make very good sense.

I think that the prominence that has been given to the matter of atomic explosives, in what has been written about it, gives quite a wrong view of its importance. I think one or two laboratories poking around on the question of the fundamentals of atomic explosives, trying out notions of how you might use a certain denatured material and prove that it would explode, would probably be all that would be involved. I do not think of this as a very large-scale activity.

There may be a period of a decade where an international agency might say of this field, "There is not anything to do; nobody has any ideas and we are not interested in improving the efficiency of atomic explosions by 5 percent." However, I think that provisions should be made to make such studies possible; and provisions should surely be made to forbid them to national agencies, because they are certainly useful in the hands of national agencies only in the measure in which they may be used in warfare.

I would add to that—and here I am differing from the United States' working paper, but I believe in a legitimate way—it does not seem to me very profitable to forbid thinking about atomic explosives. This is something the prohibition of which may be rather hard to enforce. I believe, therefore, that the prohibition should be limited to those activities which require the possession of significant quantities of nuclear fuel for being carried out because, if the international agency is good, if it is any good, it will know where the nuclear fuel is and it will know what is happening to it. Controls which are determined by this physical instrument—namely, where the material is—are certainly enforceable, if anything is.

I do not think that general staffs can be prevented from brooding about targets to bombard, carriers to carry the bombs, fuzes, or anything like that; and I would hesitate to do more than to implore them not to engage in this activity. I would hesitate to prohibit them from engaging in this activity.

I should now like to comment as to the scale of this whole activity of atomic research and development. I think the work of the development authority might, when it was flourishing, take some 10 percent of the physicists and chemists, perhaps 5 percent of the chemical engineers, and perhaps 5 or 10 percent of the mining engineers there are in the world.

This is a big activity, but it is not a preponderant activity. There would still be a great number of physicists left over to teach in the universities, to pursue human knowledge in other ways; and, as time went on, the number of physicists and chemists ought to be reduced and the number of engineers ought to increase. I will come back to that in a moment.

There ought to be several programatic laboratories, several meaning not 1 or 2 and not 100 but something of the order of a half dozen perhaps, which would give a reasonable dispersion and yet make possible rather large laboratories in which coordinated effort would be carried on. * * * Furthermore, it is important to emphasize that there should be openness, not only among these laboratories but also between these laboratories and all other laboratories of the agency, and all private, university, academic, national, and institutional laboratories. There should be complete and absolute openness.

I also extend this to the problem of atomic explosives. Knowledge about atomic explosives is, in a situation such as we are here contemplating, more dangerous if not disseminated than it is if disseminated. The possibilities of keeping secrets in this field are in any case so remote, if one has an international undertaking, that one should plan for a systematic program of dissemination and education.

I have a word to say about this, namely, that it is not enough to declare something is open. It requires instruction, it requires work to get an understanding of these things abroad. I know this from experience. I know it is not enough to tell someone a secret; it is very hard to give away a secret. You have to work at it week after week after week because these things are complex. Only the creation of a really widespread and informed understanding of the techniques of atomic energy will get work on these problems advanced rapidly and with full effectiveness. Let me explain that. The normal way in which progress is made in any of these developmental activities is that people become excited by the problem. They read about it some place; they talk about it; they have an idea and they come and say they would like to work on it. In order to further that goal, people who are not working on the problem, on the specific problem, must have a way of finding out about it. That is, they must have access to information before there is any foreseeable chance that they will make good use of the information.

It is my feeling that the agency, if it is set up, must devote itself to the cultivation of this understanding, so that the whole pool of scientists and engineers in the world will be available. Only a small fraction of them would actually participate in the work. Nevertheless, those who participate in the work should be the ones who are interested in it and have learned about it before they could prove that their learning about it would pay off.

I belabor this point because it is, to my way of thinking, the decisive reason why the development of the peaceful uses of atomic energy will prosper more under a system of international cooperation, and corresponding openness, than it possibly can under purely national systems. Under purely national systems, vast areas will remain secret. It is true that various nations may all be keeping the same secrets from each other, but they will keep them. As a result of that, the spontaneous growth and development—which is the thing that has always in the past enriched our lives through scientific discovery—will be enormously slowed down. It will not be stopped. I do not know that my time scales for atomic power are too far off even under national development, but they are certainly too short for national development and deliberately conservatively long for international development.

There are other reasons. The distraction of atomic armament is a real distraction. But these are secondary reasons compared to the enormous advantage of allowing the imagination and spontaneous interest of men to carry out this development, as it would under such conditions of international cooperation and openness.

I would make only two further comments: There is in the proposal for international cooperative development, insofar as it is a job of research and development, very little that is contrary to past patterns of scientists and technical people all over the world. It is a pattern recognized by all of us. Just for that reason, this part of the job of international control is an easy part; in this part, one can be quite confident of success.

The last comment is this: Although the primary purpose of the United States proposal was to provide security, rather than to provide freedom of research, this freedom is nevertheless a criterion by which fundamental soundness could be judged; for no proposals predicated on forbidding inquiry and learning would not, in the end, survive.

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9. JOINT STATEMENT OF UNITED STATES ATOMIC ENERGY COMMISSION AND MONSANTO CHEMICAL CO., AT OAK RIDGE, TENN.

(United States Atomic Energy Commission, Information for the Press, May 28, 1947)

The Atomic Energy Commission, with the assistance of its General Advisory Committee, has reviewed the program of the Clinton Laboratories at Oak Ridge, and the relation of that program to the overall objectives of the Commission in bringing about the rapid advancement of important projects in the field of atomic energy research and development.

The Clinton Laboratories constitute a vital part of the atomic energy program and certain projects at Clinton are among the most important in this field. In order to concentrate maximum effort on these projects, it is desirable at this time to consolidate the program at Clinton around those deemed most important.

These plans and objectives have been reviewed fully with officials of the

Monsanto Chemical Company, which has been the contractor-operator of the Clinton Laboratories during the past two years. During that time, production of isotopes, a training program, research in biology and health-physics, and work on reactors, have all made substantial progress.

The officials of the Monsanto Chemical Company have concluded that they would be able to provide the maximum effort and technical direction only if these projects were transferred to the centers of the company's research and technical activities where they could be consolidated with other important work of the company. After comprehensive review, the Commission has concluded that in the light of the overall research and development program in atomic energy, the work of the Clinton Laboratories must continue at Oak Ridge.

Both the Atomic Energy Commission and the Monsanto Chemical Company have concluded that operation of the Clinton Laboratories should therefore be transferred to other auspices. The Monsanto Chemical Company will continue to carry on important work for the Commission elsewhere on an enlarged basis. Monsanto will continue as operator of the Clinton Laboratories until its direction can be transferred, thereby insuring a minimum of interruption in this important work.

The Atomic Energy Commission will announce at an early date the new arrangements for the operation of the Clinton Laboratory. It is hoped that the present members of the staff will devote their full energies to the important and responsible task of carrying forward the program of the Clinton Laboratories.

BACKGROUND MATERIAL ON CLINTON LABORATORIES

Initial objectives of Clinton Laboratories were to produce experimental quantities of fissionable materials for use in research work essential to the development of the atomic bomb, to assemble technical information necessary to assure successful operation of a large scale production plant at Hanford, and to train some of the key men needed to operate the production plant. These objectives were successfully accomplished in the one year which elapsed between start of operations at Clinton Laboratories in September, 1943, and the start-up of the Hanford plant.

The design, construction and initial operation of Clinton Laboratories was by large numbers of top flight physicists, chemists and engineers working at the University of Chicago and at Clinton Laboratories in close cooperation with the technical and engineering staff of E. I. du Pont de Nemours and Company. Directing the project from a scientific angle was Dr. A. H. Compton, Nobel Prize physicist, then with the University of Chicago, and now Chancellor of Washington University, St. Louis.

Operation of Clinton Laboratories was taken over by Monsanto Chemical Company, St. Louis, at the request of the Manhattan Engineer District on July 1, 1945. Dr. Charles Allen Thomas, vice president and technical director of Monsanto Chemical Company, is the project director of Clinton Laboratories; Dr. E. P. Wigner, formerly professor of mathematical physics at Princeton, is now research and development director; Dr. James H. Lum, formerly assistant director of Monsanto's Central Research Laboratories, is executive director.

Employment at Clinton Laboratories has risen from a wartime peak of 1,234 to 2,150 at present.

The research program at Clinton Laboratories, currently being revised by the Atomic Energy Commission and the General Advisory Committee, covers a wide range of tracer chemistry work with radioisotopes, biological studies, and reactor design. The Laboratories will continue to be a center of reactor development for the Commission, with supporting research. Among the studies being carried out in this field is a program for the development of a reactor suitable for the generation of power.

Clinton Laboratories will continue to produce radioisotopes for distribution to hospitals and research institutions, and will carry out a joint research and training program with Southeastern Universities through the Oak Ridge Institute of Nuclear Studies.

10. STATEMENT BY MR. DAVID E. LILIENTHAL, CHAIRMAN OF THE UNITED STATES ATOMIC ENERGY COMMISSION, ON "ORGANIZATION AND ADMINISTRATION OF THE INTERNATIONAL AGENCY" ON JUNE 2, 1947 AT THE EIGHTEENTH MEETING OF COMMITTEE 2

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In this same connection, some consideration might be given to the policy, as I understand it, that is expressed, or certainly implied, in the Atomic Energy Act of 1946, the United States act, in respect to large power reactors.

That is a reactor yet to be built, yet to be designed, but a reactor which will undoubtedly someday be designed and built, which may be capable of producing heat which can be transferred to a, let us say, conventional steam turbine, and, by that turbine, produce electricity through a conventional generator. This large reactor, being dangerous in terms of security, would, on the proposals made, be designed, owned, and managed by the international agency. Similarly, and prior to that time, such a reactor—if international agreement has not by that time been reached—such a large reactor, producing electricity, would be designed, owned, managed, and operated by the Atomic Energy Commission of the United States.

But under the act of Congress, it by no means follows that because the reactor itself must be kept under the ownership, management, and operation of the Atomic Energy Commission of the United States, the electricity produced by this reactor must be distributed by the Atomic Energy Commission or by the Government of the United States. I rather infer, from certain provisions of this law, that the contrary may well be approved by Congress, namely, that at the bus bar, at the point where the electricity is produced by the generator, it will then be transferred for distribution to whatever kind of agency is the policy of that region or locality, or whatever the national policy may be in that respect; that it may be transferred to a State, that is to say, one of the States of the Federal Union, or to a private industry, or a public utility privately owned, or any one of a number of distribution agencies, depending upon the wishes of the people at that point. The fact that the production must be in national hands, in this context, does not require that the distribution should likewise be other than in accordance with the desires of the people of the local region or community. I mention that for its possible and logical value.

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11. THE SECOND SEMIANNUAL REPORT OF THE UNITED STATES ATOMIC ENERGY COMMISSION, JULY 22, 1947.

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Effecting large scale production of power.—The Commission considers the development of nuclear reactors for power production one of the more important tasks placed upon it by the Congress. It is a large and difficult undertaking. The scale and intensity of the effort that will be required to accomplish it becomes ever more evident as research on the problem continues.

A central difficulty concerns the materials of construction. The materials that go into a reactor must have certain special nuclear properties; they must be almost completely free of certain contaminants; they must be appropriate to the mechanical design of the structure; they must withstand the intense flux of neutrons and radiations seething within the reactor; finally, they must resist corrosion by the cooling medium. The researchers of the war years succeeded in finding materials which satisfied these stringent requirements well enough for the limited purpose at hand: i. e., water-cooled or air-cooled reactors operating at low temperature for experimental purposes or for producing plutonium. But power production with satisfactory efficiency and economy calls for much higher reactor temperature, much higher heat flow through the reactor structure, much higher fluxes of neutron and gamma radiation, and different cooling media. Every requirement on the construction material is tightened, and the range of materials from which a choice is possible is correspondingly narrowed.

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12. LETTER FROM DR. TELLER

LOS ALAMOS SCIENTIFIC LABORATORY,
Post Office Box 1663, Los Alamos, N. Mex., August 19, 1947.

DR. LAWRENCE HAFSTAD,
Applied Physics Laboratory, Silver Spring, Md.

DEAR LARRY: I am writing to you about a sequel to our conversation here in Los Alamos. Captain Rickover and four of his friends were up here. I am sure that you know of their interest. I was very much impressed by their enthusiasm and enterprise and also by their detailed knowledge which they picked up during their stay in Oak Ridge. I have the feeling that such people as these should be thoroughly made use of and that they should be encouraged to go ahead with an extensive program, working toward tangible results within a short time. I do not know whether they can get a first model in working order in 2 years' time, but I think they should be encouraged to try. I think what they are trying to do has a very good chance of being feasible. It need not be in competition with other enterprises because their skills are different from the skills of physicists. For instance, they are probably much more familiar with the use of high-pressure steam than most of the physicists who are now working on similar problems. I also think that they would have to draw on scientists for relatively short periods as consultants and on the whole they are capable of standing on their own feet. One of our greatest shortages is that of capable men, and I don't think we can afford not to encourage a group of people like Captain Rickover and his friends.

I have been thinking more about the specific model that we were talking about and I have made some progress. It is possible that some such thing as I had in mind would be adaptable to the use of Captain Rickover, and I would, of course, be glad to talk the specific model over with you at greater length whenever you have time. I think in the special case of Captain Rickover other models would have to be considered also, and I would not at all be sure what is the best for their purpose. The main thing is to prepare a few concrete plans, decide on one after proper consultation with people like Fermi, and then go ahead. This, I think, could be done in a few months. After that one should go ahead with that one model even if it should turn out to be in the long run not the very best possible. The experience so gained will make up for any deficiencies.

Perhaps I am overenthusiastic but I think that we have lots of good long-range plans—what we really lack is the push toward short-range objectives of which there was so much during the war, and of which there is so little now.

The reason I am writing this letter, as you can guess, is my dismay brought about by this situation: I see five Navy men, unusually intelligent, and interested in a detailed, concrete and down-to-earth plan (if down-to-earth is a proper Navy objective), but when I asked them when and how will they proceed, I am met with hesitation that seemed to me to indicate that the whole thing is not at all approved as yet, and that it is perhaps being put in the same class as some of the projects which in more ways than one are way up in the clouds.

We enjoyed your visit and hope to have more of same.

With best regards, I am

Sincerely yours,

EDWARD TELLER.

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13. CLINTON NATIONAL LABORATORY ESTABLISHED AT OAK RIDGE

(United States Atomic Energy Commission, Information for the Press, Sept. 25, 1947)

Clinton Laboratories at Oak Ridge, Tenn., first government-built nuclear research center and principal production plant for radioisotopes, will be renamed Clinton National Laboratory to become the third in the Atomic Energy Commission's national laboratories. Fourteen southern universities in the Oak Ridge Institute for Nuclear Studies and a score of industries and industrial representatives will participate in the research, development and training programs at Clinton National Laboratory.

Operation of the Clinton National Laboratory will be taken over by The University of Chicago. Negotiations for a four year contract now underway with the University are expected to permit the University to complete by December 31 the transfer from Monsanto Chemical Co., which has managed the Clinton

research facility since July 1945. During the period of Monsanto's operation of Clinton, the program of production of radioisotopes was developed and a broad peacetime program of research inaugurated.

The laboratory represents only a small part of the total operations carried out at Oak Ridge. The 59,000-acre reservation is also the center of a large number of AEC administrative operations and of the huge plants for the separation of uranium, operated by the Carbide and Carbon Chemicals Corp.

Operated since July 1945 by the Monsanto Chemical Company, the Clinton Laboratories have been maintained as a strong center for research and development work in the atomic energy program. Two of the major programs initiated during this period are the large scale production of radioisotopes and research on components for a power pile. Clinton also is an important center for general reactor research. Monsanto will continue to operate the extensive and expanding AEC facilities near Dayton, Ohio.

In a letter to Dr. Charles A. Thomas, Executive Vice President of the Monsanto Chemical Co., Chairman David E. Lilienthal of the Atomic Energy Commission, said the company "has performed an outstanding service to the people of the United States in managing the research facilities at Oak Ridge during and after the period of conversion from wartime to peacetime operations."

The letter stated that the "technical and managerial skills" of the company were evident in the development at Clinton of successful production processes for radioisotopes, and that the Commission hoped the company's participation in this work would be "of value to Monsanto in the future atomic energy industry of the United States."

A major portion of the present staff at Clinton was employed by The University of Chicago during the war and remained as part of the Monsanto organization. The entire staff will be taken over with the exception of a small number of Monsanto executive and technical personnel who will return to the company. The new Director of the Laboratory has not yet been appointed.

Arrangements for the operation of Clinton National Laboratory were worked out with the staff and industrial participants at Clinton, representatives of the Oak Ridge Institute, The University of Chicago and the U. S. Atomic Energy Commission.

The new plan of operation for the Clinton National Laboratory brings together the Oak Ridge Institute of Nuclear Studies, interested industries, and The University of Chicago, original contract-operator of the Clinton facilities. Plans for the original reactor (pile) and other facilities at Clinton were made cooperatively by the E. I. du Pont de Nemours Company and the Metallurgical Laboratory at The University of Chicago. Construction was carried out by du Pont and plant operation was maintained by The University of Chicago as a part of the Metallurgical Project until July 1945.

The participation of the Oak Ridge Institute for Nuclear Studies in the Clinton National Laboratory program brings to 52 the total number of non-governmental research institutions in the AEC national Laboratory program. Argonne National Laboratory at Chicago, successor to the war-time Metallurgical Laboratory at The University of Chicago and first of the national laboratories to be established, has 29 participating institutions throughout the Midwest. It is operated by The University of Chicago. Brookhaven National Laboratory at Patchogue, L. I., is operated by Associated Universities, Inc., which is composed of nine eastern universities.

Establishment of national laboratories was recommended by the Manhattan District's Advisory Committee on Research Policy, headed by Dr. R. F. Bacher, then of Cornell University and now a member of the U. S. Atomic Energy Commission. A major objective of the national laboratory plan was to utilize to the fullest possible extent the research personnel and facilities of academic and industrial institutions throughout the United States and to make possible a program of training in the nuclear sciences. The concept of national laboratories has been vigorously supported by the Atomic Energy Commission. Through the national laboratory program the AEC plans:

1. To make all national laboratories strong centers in the field of atomic research.
2. To develop Argonne National Laboratory and Clinton National Laboratory as parallel but separate and independent research and development institutions.
3. To emphasize reactor research and development at the Argonne and Clinton laboratories.

During the war The University of Chicago operated both the Clinton Laboratories and the Metallurgical Laboratory where the first successful nuclear chain reactor was developed and first operated on December 2, 1942, beneath the University's West Stands of Stagg Field. The Metallurgical Laboratory conducted fundamental research on problems bearing on the design and operation of the Clinton experimental reactor, and together with Clinton, on the production piles at Hanford, Washington, and on the development of plutonium recovery processes and equipment. Consequently, The University of Chicago has been associated with the research, design and development work on nuclear reactors and allied equipment from the earliest days of the atomic energy project.

The program to be carried out by the Clinton National Laboratory includes the following major projects:

1. Continued production of radioisotopes.
2. General research, including both applied research in connection with other AEC activities and fundamental nuc'ear research.
3. Design and construction of a new high-flux reactor several times more powerful than the existing Oak Ridge pile for further studies and expanded research requiring neutron intensities not now available.
4. Continuation of engineering studies for the development of components of reactors for the production of useful power, in cooperation with representative engineering and industrial firms.
5. Operation by the Oak Ridge Institute of a school for academic and industrial personnel, and of a program of on-the-job training by qualified graduate students with provision for credit toward advanced degrees.

The Oak Ridge Institute of Nuclear Studies was formed last year to promote activities in nuclear sciences in southern universities and to carry out a program of joint research and training utilizing the government facilities at Oak Ridge.

Present members of the Oak Ridge Institute of Nuclear Studies are:

Alabama Polytechnic Institute, Auburn, Ala.
Catholic University of America, Washington, D. C.
Duke University, Durham, N. C.
Emory University, Atlanta, Ga.
Georgia School of Technology, Atlanta
Louisiana State University, Baton Rouge
Tulane University, New Orleans, La.
University of Alabama, Tuscaloosa
University of Kentucky, Lexington
University of North Carolina, Chapel Hill
University of Tennessee, Knoxville
University of Texas, Austin
University of Virginia, Charlottesville
Vanderbilt University, Nashville, Tenn.

While the Oak Ridge Institute of Nuclear Studies is incorporated in Tennessee and is composed entirely of southern universities, the Institute has established a policy of making all of its research and educational programs at Oak Ridge national in scope and open equally to all universities in the United States. The fourteen southern universities have accepted membership in the Institute as sponsors of a national program and no special advantages are enjoyed by the member institutions.

Officers of the Oak Ridge Institute are:

President: Dr. Frank P. Graham, President, University of North Carolina Consolidated

Vice-President: Dr. Frederick Seitz, Professor of Physics, Carnegie Institute of Technology, Pittsburgh, and former Director, School of Advanced Training, Clinton Laboratories.

Treasurer: Dr. William G. Pollard, Professor of Physics, University of Tennessee.

Directors: Dr. Jesse W. Beams, Professor of Physics, University of Virginia
Dr. Ernest W. Goodpasture, Dean and Professor of Pathology, Vanderbilt University Medical School
Dr. Paul M. Gross, Professor of Chemistry, Duke University
Dr. Theophilus S. Painter, President, University of Texas
Dr. George B. Pegram, Dean of the Graduate Division, Columbia University, New York
Dr. Eugene P. Wigner, Professor of Physics, Princeton University and former Director for Research, Clinton Laboratories

The present program of participation of interested industries in the basic engineering research on a power pile at Clinton National Laboratory will be continued and expanded to bring into the national atomic energy project the needed technical experience and skill of private industrial and engineering organization.

The training program conducted in the Clinton Laboratory during the past year was attended by engineering and research staff members of a number of interested industrial concerns. Their activities included advanced studies related chiefly to reactors as well as participation in research and development programs of the laboratory.

Representative groups affording working members to the Power Pile Division at Clinton are:

Allis Chalmers Manufacturing Co., Milwaukee, Wis.
Babcock & Wilcox Co., New York, N. Y.
Bureau of Ships, U. S. Navy Dept., Washington, D. C.
Combustion Engineering Co., Inc., New York, N. Y.
Fredric Flader, Inc., Tonawanda, N. Y.
General Electric Co., Schenectady, N. Y.
National Advisory Committee for Aeronautics, Washington, D. C.
National Carbon Co., Inc., Cleveland, Ohio
Northrup Aircraft, Inc., Hawthorne, Calif.
Tennessee Valley Authority, Knoxville, Tenn.
Purdue University, LaFayette, Ind.
Wright Aeronautical Corp., Woodbridge, N. J.
Westinghouse Electric Corp., Pittsburgh, Pa.

Individuals and industrial companies who are performing consultant service with the Power Pile Division are:

Allis Chalmers Manufacturing Co., Milwaukee, Wis.
Air Reduction Sales Co., Stamford, Conn.
Babcock & Wilcox Co., New York, N. Y.
Dr. F. H. Colvin, Point Pleasant, N. J.
Combustion Engineering Co., Inc., New York, N. Y.
Dr. Farrington Daniels, University of Wisconsin, Madison
De Laval Steam Turbine Co., Trenton, N. J.
Foster Wheeler Corp., New York, N. Y.
Fredric Flader, Inc., Tonawanda, N. Y.
General Electric Co., Schenectady, N. Y.
National Carbon Co., Inc., Cleveland, Ohio
Purdue University, LaFayette, Ind.
Donald W. Randolph, Cleveland, Ohio (Apex Mfg. Co.)
Westinghouse Electric Corp., Pittsburgh, Pa.
J. B. Willard, University of Wisconsin, Madison
Wright Aeronautical Corp., Woodbridge, N. J.
J. I. Yellot, Research Director, Locomotive Development Committee, Baltimore, Md.

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14. ATOMIC ENERGY AND AMERICAN INDUSTRY

Address by the Honorable David E. Lilienthal, Chairman, United States Atomic Energy Commission before the Economic Club of Detroit, Detroit, Mich., October 6, 1947

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There are a great many questions that are asked about atomic energy these days, and some of them relate to the prospects for its industrial use; it is to those that I am addressing myself today.

Among those questions are, specifically: What are the prospects for electric power from atomic energy, for factory, and home, and farm? What about atomic power plants for surface ships and submarines, for airplanes and guided missiles? Are those things right around the corner? When can we expect a substantial part of this country's energy requirements to come from atomic energy plants? Can power and heat from atomic energy solve the coal problems of Britain and France and help put Europe back on a self-supporting basis in the next few years? Should the power industry slow up their plans for expansion of steam-generated power? Should Congress drop the St. Lawrence power project and call a halt on California's Central Valley, and on other irrigation projects in which water power is a major factor? Should insurance com-

panies and other investors in the power industry begin to worry about the effect of atomic energy on their holdings?

Such questions as these could be extended into a considerable list. They are important questions.

The course of American industry and indeed the whole of American economic life is involved in the answers. Therefore the people of this country are entitled to candid, straightforward answers, based upon the best available information and judgment. The only important limitations on that fundamental right is the sensible rule that where, on balance, the national security would be adversely affected, information regarding atomic energy must be kept secret from the public. We ought constantly to remind ourselves, and in no uncertain terms, you ought to remind your public servants, that to withhold information on public matters, from the people, in peacetime, is a radical departure from our traditional ideas of the accountability of public servants.

As to the prospects of atomic power, let me say at the outset that in our opinion the long-time prospects of atomic power are bright indeed. America's leadership in atomic energy research and production is one of our Nation's great assets.

But the fact should be faced squarely that the first commercially practical atomic power plant is not just around the corner, not around two corners. Before that first commercial plant will be possible, we must first cut through a jungle of difficult scientific and engineering problems. And even after the scientific and engineering underbrush has been cleared away, and a commercially useful plant of some size is in successful operation, there are other barriers that must be overcome before any substantial part of our energy supply—say 10 to 20 percent—comes from atomic energy.

Now this does not mean that within the next 12 to 24 months useful electric power could not be actually developed from a nuclear reactor, that is to say, from atomic energy. Such atomic power could turn motors and light bulbs, and heat buildings. As a matter of fact, on a demonstration basis that could be done. It almost certainly will be done. But what is certainly and definitely not near at hand are large-scale, practical commercial applications of power from atomic energy.

It is obvious that the economics of power production from nuclear reactors cannot be divorced from the scientific and engineering problems. But as of today there is as yet no firm basis for estimating the competitive cost position of useful power from nuclear sources in comparison to the cost of generating power from conventional fuels.

But let me pause here for a moment to emphasize the international importance of a frank statement of our conclusions that large-scale power is not just around the corner.

The following story is being spread in foreign nations by those unfriendly to our democracy, as well as by others who are friendly to our American democracy but uninformed, and they say:

"Here we are facing another winter. Lack of coal will close industry in England, France, Germany, Austria, perhaps Belgium. People will be cold, will freeze, be out of work. The United States could have prevented this; she could prevent it happening again. For the United States has the secret of atomic energy, and in that secret is the answer to limitless, almost costless energy and heat. Only America's military imperialistic passion stands in the way of solving Europe's most crying need, a new source of energy and heat."

Now, this story is completely without foundation in fact. There is no basis whatever for this charge, none whatever. An important purpose of my remarks here today is to say just that, and to state in outline as best I can within security limitations the scientific and engineering reasons why no one can count on atomic energy to solve the fuel problems of Europe and England within the foreseeable future.

In point of fact, the immediate importance of the discoveries concerning nuclear fission does not seem to me at least to be as a new source of heat and electricity at all. That immediate importance, for industry and for all of us, lies rather in the fact that here is one of the most powerful levers that has ever come to the hand of man by which he can pry open new doors of knowledge, long closed to him, new fundamental knowledge about the nature of matter and life itself.

The subject I have chosen to discuss here today—Atomic Energy and American Industry—is obviously far broader and more immediate than simply the prospects for atomic power. American industry is vitally concerned with the military

use of atomic energy, such as current proposals for decentralization of cities and the relocation of industry underground. The subject includes the whole field of present industrial and business opportunities in this field—as yet unrealized. Among these are the early manufacture and sale by private industry of molecular compounds containing radioactive and stable isotopes, among them carbon. The isotopes are now produced by the Commission in some quantities in the atomic furnaces at Oak Ridge. This field includes the possibilities of the use of such radioactive tracers in industrial chemical process control, in research problems, and in oil-well surveys throughout the petroleum industry, as well as in hydrocarbon cracking processes. The subject includes the steps the Commission has already taken, and others it will shortly take, to insure industrial and engineering participation, from the very beginning, in the design of power reactors. It includes, as an early prospect, the whole attractive outlook in the use of reactors producing beams of very high neutron intensity for the treatment of many kinds of materials, chief among them metals. This may well soon open a new era in metals for industry. It includes the training of engineers and industrial men generally in these new fields, so that American industry can keep abreast of new developments as they occur, and in this way help protect against any tendency toward inertia and complacency that the existence of the present Government monopoly may bring with it, for this inertia is an always-present danger with most monopolies, whether governmental or private.

We seek industrial guidance because we believe that unless American industry and American engineering skills become an active living part of the Atomic Energy Commission's undertaking, the expectations and the needs of this country in this field will be inevitably doomed to disappointment. This subject, therefore, of "Atomic Energy and American Industry" is not something which the average American can pass over as a matter of remote concern to him. The health and vitality of this relation of your atomic-energy project to American industry and engineering determines to a very large extent the military security of this country. The man on the street as well as the industrial executive and the industrial engineer are all directly involved.

There is a difficulty, a very real difficulty, in achieving the active widespread guidance and participation of American industry and engineering that is so essential in atomic-energy development. That difficulty is the continued need for secrecy in important sectors of this work. This must be candidly recognized and it should be spoken of openly and faced frankly.

Atomic energy, as Dr. Sawyer has indicated and as we all know, constitutes the basis of the most devastating and overwhelming weapon man has ever devised. The project was, therefore, conceived in secrecy; it was carried forward secretly; and a need for secrecy continues today.

Government-imposed secrecy and industrial progress in peacetime are not cut out of the same cloth. Government-imposed restrictions upon any part of atomic-energy development are not calculated to invite and encourage that ferment of ideas, that self-criticism, that competition, that cross-fertilization between skills that has given America its industrial strength and vigor. If, when the automobile was first developed, it had been developed under Government auspices because of its value for military purposes; and if secrecy had been imposed upon knowledge of the internal-combustion engine, and if the military had been the sole customer for automobiles, you can imagine how this would have impeded the development of the automobile as a principal factor in the every-day life of America.

This is not wholly an imaginary possibility, for you may recall the story of Gaspard Mongé. Mongé devised the system of descriptive geometry which forms the very basis of all engineering plans and elevations. But because he worked this out as part of a "classified project" for Napoleon, descriptive geometry was covered with top-secret stamps for a quarter of a century.

The necessity for secrecy at vital points at this stage in world affairs is certainly clear. Nor has anyone ever proposed that at this time the atomic energy project—this huge industrial and scientific undertaking—could be turned over to private competitive production and relieved completely of security limitations. There seems now to be no alternative to the present course.

Here then is a situation unique in the history of American industry.

The Atomic Energy Commission certainly believes that this atomic industry can never flourish and grow and find its proper place among the elements of our national strength unless it sends its roots deep and wide into the same soil that has nourished the automotive and other industrial giants, the soil of competitive private industry. But the business of making atomic power happens, unfortu-

nately, to be the same as the business of making atomic bombs, up to a point very far along in the process. The Congress last year had no choice, wishing as it did to maintain Government control of atomic weapons, except to give both the weapon development and the possible power development over to the care of a single Government agency.

But the Commission does have some room for choice in deciding whether the work of a Government industry shall be carried on chiefly by the Government directly, or chiefly by American industry as agents and contractors of the Government. The Commission has pursued the latter course. We do not forget that the mammoth developments inherited from the Manhattan District were built, improved, and operated by American industry, under Government direction. With these monuments of achievement before us, we are not likely to underestimate the role which industry can play, and must play, in the development of this field toward peaceful ends. We want this enterprise to enlist a widening area of our economy, so that progress will be made rapidly and effectively, and so that an atomic industry, when it is possible for it to grow by itself, will not find it has been planted in shallow soil. Correspondingly, we want to keep the governmental machinery for managing and directing this enterprise as small as it possibly can be.

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Until these, and several other problems of this kind which may not now be discussed have been worked over, hard, we do not have, we believe, a satisfactory basis for the engineering design of an atomic power plant. In Commission laboratories over the country, and in industrial laboratories and institutions, these problems are being studied. The ultimate objective is a reactor to operate at a rather high temperature. From such a reactor useful power will be extracted, but this reactor will use a very expensive form of nuclear fuel—plutonium or the rare enriched uranium, U–235—in all probability. For all but very special uses, this fact puts a high premium on efficient processes for separating the radioactive poisonous fission ashes from the unused nuclear material. And these have yet to be developed, although the work is now underway.

This, then, is a partial list of the technical problems which must be solved before atomic energy for peaceful purposes will be available to the United States. The problems dictate the kind of research and development program that has to be undertaken. Much of the work at the moment is not engineering work, because the fundamental scientific information on which the engineering could be based simply does not exist. As the research shows the way into development, and the development leads finally into the application, the Commission will, of course, turn at each phase to the group or groups best equipped to solve the problems before us. The work as we see it now will lose its predominantly scientific tinge and will become the work which American engineering and industry can do well and should do, and I have no doubt will.

The final question is that of a time estimate. Just when will the first atomic power plants begin to appear? How fast can the industry grow?

Answers to such questions as these cannot be precise. It would be not quite truthful to say that your guess is as good as mine, but I don't believe anybody's estimate is more than an educated guess. All our technical advice is clear that we can be confident of success. The date has to be shifted back and forth with every report of disappointment, or of "pay dirt" that comes from the laboratories and facilities.

How many years will this be? This much you can count on: If we don't go at it with vigor and a sense of urgency, if we go to sleep on the job, it will take a hundred years.

As our staff and technical advisers see it now, it will be a long, hard grind. The most common estimate or guess is from 8 to 10 years to overcome the technical difficulties and have a useful practical demonstration plant in operation.

Short cuts will be found, of course, and clever inventions and discoveries will be made with respect to each one of the technical problems I enumerated for you earlier. However, we do not now see any reason for hoping for a major short cut around the whole mass of technical problems, or the other limitations not here discussed. There is not any reason to expect that an atomic energy industry will spring into being overnight and make its appearance as a colossus upon the national scene, displacing at once the power installations which now serve us and disrupting in a few years the whole pattern of our economy. Atomic power will come by way of supplementing rather than supplanting existing sources of energy supply.

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In our opinion, no one should delay sound and economical additions to power supply, whether by fuel-generated electricity or water power, because somewhere in the future atomic energy will come on the scene as an additional source of supply.

The Atomic Energy Commission pledges that American industry and engineering will be kept informed of developments in this field. When, as in this discussion, the information cannot be complete, we will tell you so. Atomic energy is your business, the people's business, and you have a right to know. More than that, unless industry does know, and unless it is a participant, atomic energy development will suffer, and we shall have failed in our obligation to the public.

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15. THE METALLURGIST AND ATOMIC ENERGY

Speech by Robert F. Bacher Before the American Society for Metals in Chicago, October 23, 1947

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While the metallurgist has played a vital role in the development of atomic energy, the job is just well started. Looking forward, it is possible to see that the accomplishments of the war are but the prelude to those which will be necessary for the long-range development of nuclear reactors. The present nuclear reactors which produce plutonium from uranium subject the structural materials of the reactors to very unusual conditions. In addition to the very high rate of heat generation from the process of fission, all of the materials comprising the interior of the reactor are subjected to the most violent radiation from the fission process. These radiations may change the physical properties of the materials very considerably.

It may turn out that the physical changes produced in nuclear reactors will lead to the use of reactors for the production of materials with properties not otherwise obtainable. Treatment in a nuclear reactor may become a procedure for production of special metals and other materials. It is too early, however, to consider such a suggestion as more than speculation.

But this is only the start. Up to the present, we have worked with reactors in which the demands upon the structural materials have been relatively small compared to what we foresee for the future. For example, the present nuclear reactors operate at relatively low temperature. Furthermore, the intensity of the radiations to which the materials are subjected, while high by ordinary standards, is relatively low compared to that to which materials will be subjected in the future.

The successful development of reactors which can be used for the production of electrical power from the atomic nucleus depends upon the development of higher temperature nuclear reactors. It is true, of course, that electrical power from the atomic nucleus depends upon the development of higher temperature nuclear reactors. It is true, of course, that electrical power could, as a demonstration, be produced from the low-temperature reactors which now exist, but this would not be the basis for a practical development. In order to obtain a high efficiency in the conversion of nuclear energy into electrical energy, it is essential that higher temperature reactors be devised and built.

Now, such a development looks quite possible at the present time. The future looks quite promising, but there are a great many difficulties to be overcome. When one starts to search for a material which will be usable in a nuclear reactor, he must, first of all, look to its nuclear properties. Unlike the specifications for most of the other uses to which metals are put, when used in a nuclear reactor the fundamental nuclear properties are vital. If the nuclear properties of a material are unfavorable, all other favorable qualities are of no use. The nuclei of some atoms have an absorbing power a million times greater than the nuclei of other atoms for the neutrons with which the nuclear reactor is flooded. The tremendous effect of a small amount of impurity becomes immediately apparent.

In the construction of the first reactors, almost every other quality had to be sacrificed in order to make the reactor work. For the future development, these conditions may be not quite so stringent. There is now the possibility of using purified fissionable material. The construction of a reactor with such purified fissionable material is very much easier, and the amount of neutron-

absorbing material which may be used in the reactor is somewhat greater. It is true, of course, that the use of too much absorbing material may make the reactor inefficient so that this limitation still is with us. But the number of possibilities will be increased for the future reactors.

The requirements put upon the materials will ever be greater. The development of suitable materials which will stand up to the conditions to which they are subjected at high temperature has barely begun. Still much higher temperature than that needed in reactors for the production of electrical power will be demanded if atomic energy is ever to drive an airplane. Such a development will not be successful without the aid of metallurgists. The very greatest ingenuity will be necessary.

The nuclear requirements may be such that it will be necessary to prepare separated isotopes for these materials in sufficient quantities that they may be used as vital constituents in the structure of certain reactors. At the present time, the whole subject of reactor development and the detailed knowledge of the nuclear properties of the various materials is insufficiently well determined to tell whether such a course will be necessary. It will greatly simplify the problem if it is not. Only by the very closest cooperation and collaboration between those who are skilled in the development of new materials and those who are concerned with the nuclear aspects of reactors will these questions be answered.

It is not only for the production of electrical power that the development of nuclear reactors is needed. These nuclear reactors produce fissionable material. This fissionable material is the vital substance either as nuclear fuel to be burned in other reactors or as the vital component of the atomic bomb. In either case, it is the fissionable material which is the key. Production of this material, as well as the production of power and nuclear engines, is closely tied to the development of nuclear reactors which will be a tremendous advance over those now in operation.

The development and further exploitation of atomic energy—whether it be for the peacetime developments or whether it be in the production of weapons—is intimately tied to the development of materials with properties which we have never seen before. In this work, metallurgists must play a leading role if the development is to be successful. Here is a new field which is vital to the country opening before you.

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16. AEC CONSOLIDATES REACTOR RESEARCH AND DEVELOPMENT AT ARGONNE NATIONAL LABORATORY NEAR CHICAGO; ENTERS NEW CONTRACT FOR CLINTON NATIONAL LABORATORY AT OAK RIDGE AND ADDS CHEMICAL ENGINEERING DEVELOPMENT AT THAT LABORATORY

(United States Atomic Energy Commission, Washington 25, D. C. Information for the Press, No. 80, December 31, 1947)

To speed research and development work on basic phases of the Nation's atomic energy program, the United States Atomic Energy Commission today announced several changes in the location of projects and in contractors for operation of the projects.

Major phases of the realinement in research are as follows:

1. Reactor development previously planned for both the Clinton National Laboratory at Oak Ridge, Tenn., and for the Argonne National Laboratory near Chicago will be consolidated at the Argonne National Laboratory under the direction of Dr. Walter H. Zinn.

2. In carrying on its program (other than new reactor development) the Clinton National Laboratory will develop a strong project for research in chemical and chemical engineering problems involved both in the production operations carried on by the Commission and in the solution of fundamental chemical problems in the broad field of nuclear energy, with emphasis on industrial applications.

3. The contractual arrangements for the work at Clinton National Laboratory have been changed. At the request of the Commission, the University of Chicago has withdrawn from the contract for operation of this laboratory which it was to have assumed January 1, and will center its effort on operation of the expanded program at the Argonne Laboratory under the new arrangement. At the

Commission's request, the Monsanto Chemical Co., which was to have retired from operation of the Clinton National Laboratory on January 1, will continue in charge until the new contractor assumes operations. The new contractor, under agreement now being negotiated, is the Carbide & Carbon Chemicals Corp., already the contract operator of the production facilities for U–235 maintained at Oak Ridge. This industrial concern has been asked to take over also the Clinton National Laboratory management because of the increased emphasis to be placed there on chemistry and chemical engineering, with the development of broad industrial participation in the program of this laboratory.

The Commission's decision to center the reactor work in one laboratory was unanimously concurred in by the General Advisory Committee established under the Atomic Energy Act of 1946 and composed of leading scientists and engineers in the field of nuclear energy.

The Commission explained that consolidation of reactor research and development is essential in order to secure the maximum results from the work of the limited number of scientists and technicians qualified in this field. This phase of the research program now will combine the efforts of those who have been working at Clinton National Laboratory on design of a high flux reactor and studies of power reactors, and those who have been working at the Argonne National Laboratory on their reactor program.

Each of these projected reactors will open new fields of knowledge of theoretical and applied nuclear energy which cannot be studied with existing reactors. It is believed that by bringing together in one location the skill of the scientists, engineers, and technicians now assembled separately the development of all the projects can be speeded. Advance in studies carried on through reactors is basic to future development of atomic energy for all uses.

The Clinton National Laboratory will continue to operate as a research tool the graphite reactor now there and the related chemistry and physics work. It will continue also as the Commission's center for development in isotopes work and distribution and a focus for research in biology and health physics.

The Oak Ridge Institute of Nuclear Studies, organized by 14 southern and southwestern universities, will continue unchanged in its relation to Clinton National Laboratory, carrying forward its program of study and training.

The Argonne National Laboratory will continue and will further expand and develop its extensive research program in the related basic sciences in cooperation with 29 associated research and educational institutions of the Middle West.

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17. SUGGESTED AREAS FOR CONTINUED RESEARCH

(From Survival in the Air Age, a Report by the President's Air Policy Commission, January 13, 1948)

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Atomic propulsion.—The possibility of employing atomic energy for the propulsion of aircraft and guided missiles is sufficiently important to warrant vigorous action by the Atomic Energy Commission, the Air Force, the Navy, and the NACA. Some work of a preliminary nature has already been done in this field by the AEC, the Air Force, and its NEPA project. Immediate steps should be taken to intensify research effort in this field under a plan which would be supported by all of the above agencies and under which the project would be given the benefit of all the background information in the atomic field actually needed by the recipients for the appropriate performanace of their respective functions.

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18. REMARKS OF DR. ROBERT F. BACHER, MEMBER OF ATOMIC ENERGY COMMISSION, BEFORE THE OAK RIDGE ROTARY CLUB, JANUARY 15, 1948

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The possibilities in nuclear reactor development are great. For example, we know from the piles at Hanford that we may expect to obtain great quantities of energy, the amount of energy depending on the particular reactor which one is considering. This energy can be put to useful ends and so inevitably has great

possibilities. For example, this energy can be used to replace the heat obtained from coal and may thus be used to generate electric power. There are many specific ways that nuclear power plants can be used. For example, such a power plant would be very useful on a ship. As you know, work is going forward in the NEPA program here at Oak Ridge on studies to determine if a nuclear power plant is a feasible thing for an aircraft.

In connection with development of a nuclear reactor that could operate economically as a source of electric power, I think such a program will take from 5 to 10 years. I put it as vaguely as that because it depends on how much effort can be concentrated on it in the next 5 years. But I think that 10 years would not be an unreasonable figure.

In thinking about the production of electrical power by nuclear reactors, some people have an idea that it might replace all forms of generation of electrical power. I think such complete replacement is unlikely. In the first place, the power capacity of the United States is so extremely great that even if we had a plant that was capable of generating power and knew exactly how to build it, it would take many years to get enough of these plants in operation to replace a sizable portion of fraction of the power facilities in the United States. And actually, we don't know today how to make such a plant which will operate economically. Despite the pessimism of some, however, that the power development will never materialize because of the many difficulties involved, my own conviction is that we can expect great advances in the next 10 years in reactor development and that a demonstration in the use of nuclear energy to produce electrical power is possible in 2 years.

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19. THE THIRD SEMIANNUAL REPORT OF THE UNITED STATES ATOMIC ENERGY COMMISSION, FEBRUARY 2, 1948

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6. *Power.*—Because of the relationship between the rate of reproduction of fuel in a breeder and the power of the reactor, the development of breeders and of reactors for power will go hand in hand. There is, in effect, a complete interlocking of the scientific and engineering problems of the breeder and the power reactor, with both heavily influenced by our ability at any given time to procure, recover, and process efficiently and with reasonable economy the required fuels.

The generation of significant amounts of useful power from nuclear energy depends upon no single factor of availability or utilization of fissionable materials, but upon a complex pattern of developments in the fields of exploration and processing of raw materials, reactor working materials, chemical separation systems, and reactor design and operating techniques. The development work to be done in these fields and the periods of time required to produce usable amounts of new fuel through "breeding," introduce a time factor measured in years into any discussion as to when nuclear energy can make a significant contribution to the supply of power now available from other sources.

It was with these facts in mind that the Chairman of the Commission expressed the Commission's views on these prospects in an address before the Detroit Economic Club on October 6, stating that "the first commercially practical atomic power plant is not just around the corner, not around two corners," and that a common estimate of the time schedule for the development of nuclear power "is from 8 to 10 years to overcome the technical difficulties and have a useful, practical demonstration plant in operation."

A reasoned view of the prospects for significant amounts of useful power from nuclear energy—at least for limited practical applications—is an encouraging one. But the timetable extends through two decades.

In a recent paper discussing the scientific and engineering problems of power, the General Advisory Committee said:

"Assuming even a most favorable and rapid technical development along these lines a word of caution is needed as to time scale. We do not see how it would be possible under the most favorable circumstances to have any considerable portion of the present power supply of the world derived from nuclear fuel before the expiration of 20 years."

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20. REMARKS OF COMMISSIONER SUMNER T. PIKE, UNITED STATES ATOMIC ENERGY COMMISSION, BEFORE THE NATIONAL INDUSTRIAL CONFERENCE BOARD, THE WALDORF-ASTORIA HOTEL, NEW YORK CITY, MARCH 18, 1948

The problem of net, usable power from nuclear reactors seems to divide itself pretty neatly into two parts. First, can such power be obtained at all? And, second, if the answer to the first question is "yes," how soon and how far can it be expected to enter into competition with other power sources? The first question can, I believe, be answered affirmatively with the qualification that there is a considerable time element involved. This can hardly be expected to be less than 5 years, and might last as long as 10 or 15. I think you may have noticed that we expect to get some power out of a reactor now under construction at Brookhaven, Long Island, and we hope to get this power somewhere around the end of 1949. However, this reactor is not being built primarily for power production and our best guess at present is that it may produce about enough to operate about one-half of the auxiliary equipment such as pumps and blowers which are a necessary part of the reactor set-up.

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Now, let us try to examine the second half of the question, which is that of economic competition with other methods of producing power. I suppose it is a fair approximation to say that the cost of power from any source is made up of its capital cost, its operating cost, and depreciation or obsolescence. Hydroelectric power, as we know, normally has a high capital cost, a very small operating cost, very small depreciation, and since a good hydroelectric plant operates close to top theoretical efficiency, almost no obsolescence. A steam plant—and now we are talking about the boiler end of the steam plant, since the nuclear reactor as power producer is merely the boiler end of the plant—the steam plant has characteristically a low capital cost, a high operating cost, largely for fuel consumption and a medium rate of depreciation or obsolescence which, since the initial capital cost is quite low, has little effect on the ultimate cost of power. When we get to the question of cost of power for atomic energy, we might as well admit at once that we are all at sea on each one of the major factors of cost. Until we have made a machine that will operate at all, we can't have any accurate idea of the capital cost. Any cost estimates based on the presently available scanty data would indicate that the capital cost alone would be so high that if ever there were no operating or depreciation factors, interest on the capital alone would make the atomic power plant noncompetitive as against present methods of power production. This, however, should not be taken very seriously because as soon as the first practical working prototype is in operation, then the matter of capital costs can and will be seriously attacked, and if previous history is any indication, good research development and engineering skill will effect radical reductions. Operating costs will probably be high in the first instance. Only the future can tell about the cost of fuel. If exploration for large deposits of uranium is successful, which is a reasonable hope, operating costs for fuel can be pulled down into the practicable range. This is a question which only time and effort can solve and effort is being expended in this search. Labor costs on nuclear reactors will tend to be high at first, but as we work from the experimental zone it should be lowered gradually. When it comes to depreciation and obsolescence, we can expect to have very high rates at first and have no reasonable hope of expecting ever to get down to the low rates applicable to hydroelectric power production.

The heavy shielding required for protection against health hazards would seem to eliminate in the present state of knowledge any use of atomic power for small, mobile units. But for a use like that of ship propulsion, where the added weight of the plant might be more than offset by elimination of vast quantities of fuel for long voyages, atomic power looks quite promising. One would be inclined to guess that at first, successful use might come for naval propulsion where the ability to keep at sea for long periods without refueling might well outweigh higher unit operating costs. For use on land, considering the weight and bulk of the necessary installations, a large reactor comparing in output with some of the largest central stations now being built, would have the best promise of reasonable costs. In such a case it would come into direct competition with present sources of power. If it ever is to compete at all, it seems clear that where coal or its equivalent costs $20 a ton, atomic power will be used long before it will be considered in areas where coal costs are $6. To try to look farther ahead gets us more and more into a fog.

At this time I think I should recapitulate the story and leave it.

As I said in the beginning, the problem is first whether the nuclear reactor can produce net useful power at all. To that, I think the answer is "Yes," and the time period is considerable—let's say 5 to 15 years.

Secondly, taking the answer to the first question as "Yes," we do not know enough about any of the major elements of cost to be able to say flatly whether it will or will not compete with present sources of power. But, from the little we do know and what we can infer, we believe that it can fit, first, in places where power costs are a minor factor or where present power costs are very high. Anyway, my own guess is that it will for many, many years never do more than supplement other sources of power to supply what seems to be an accelerated growth in world-wide demand.

There is one consideration that I did not mention in my previous remarks. That is, that reactors which are built primarily for other purposes also produce heat which, as in the case of the Brookhaven reactor, can be used to produce auxiliary power. It is very possible that with improved design, such reactors may have power for disposal as a byproduct and, of course, it is normal to expect that if this turns out to be a fact, such power will be sold on the market for what it will bring—the revenues to be used as a credit against the cost of reactor operation.

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21. NAVY BUREAU OF SHIPS NUCLEAR POWER PROGRAM

By Vice Adm. E. W. Mills, United States Navy, delivered before the Undersea Warfare Conference in Washington, D. C. April 2, 1948

We have come to a point in submarine design where it appears feasible to obtain a *true* submarine. We have never had such a submarine.

Until an experimental submarine nuclear power plant is designed and constructed we will not have a *true* submarine.

Another important factor which makes development of a nuclear power plant for submarines mandatory is that when such a development is successful the United States will have the choice of using or not using available fissionable material in the power plant. If this development is not undertaken *now*, there will be no choice, and our national defense will suffer accordingly.

Admiral Parsons, in his talk, emphasized this point when he stated that the possible gains in military potency are so decisive in the case of submarines and aircraft that they fully justify development of nuclear reactors for these specific applications. And that failure to do this would be the worst sort of gamble.

The importance of nuclear propulsion for submarines has also been recognized by the Committee on Undersea Warfare. In a recent report, that Committee stated that if a submarine could be developed which is capable of performing its entire mission submerged, a complete revolution in undersea warfare will be required. I will quote from the report:

"It will be analogous to the introduction of the long-range bomber, and though its land targets would be limited to those which can be reached by air missiles launched during brief periods on the surface, it would be relatively less vulnerable to defensive measures than is the long-range airplane. If it is quiet, and can submerge deeply, there is little chance of detecting and countering it by airplane. It will also be relatively immune from detection or attack by surface craft. Its detection and countering by other submarines will be limited by the shortness of range inherent in sonar methods. It will represent a major improvement in methods of attack, for which adequate methods of defensive countering will be almost as lacking as for high-altitude rockets."

Another aspect of the situation that I must impress upon you is that during the recent war there was an almost complete exchange of technical knowledge and engineering design among the Allied Nations. If we are to regain our lead in the submarine field we must find advanced means of propulsion. Nuclear power offers us such a means.

So much for the importance of nuclear propulsion for submarines. A pertinent question at this point is, "What has been done to develop nuclear propulsion?" And this is what I will now talk about.

The Bureau of Ships has been interested in nuclear power for ship propulsion since 1939, but during the war all of its efforts in this line were applied to support the Manhattan project in isotope separation for bomb use.

But even during the war the importance of nuclear power was realized by the Manhattan project. In 1944 General Groves appointed a committee to look into

this possibility. This committee consisted of Dr. R. C. Tolman, Dr. W. K. Lewis, and myself. The exigencies of the war naturally prevented diversion of effort to this field at that time.

Early in 1946 the Manhattan project started work on nuclear power at Oak Ridge. A number of industrial organizations and the Bureau of Ships, were invited to participate. Accordingly a group of five officers and three civil-service employees were assigned to Oak Ridge to join in the work on this power pile.

Also, in 1946 the General Electric Co. entered the field of atomic energy and undertook to build an atomic power laboratory at Schenectady as an adjunct to the operation of the plutonium piles at Hanford. The General Electric Co. has had long experience in ship propulsion and was willing to work out a plan with the Bureau of Ships and the Manhattan project whereby they would undertake a study of a propulsion plant suitable for a naval vessel. Such a study was commenced late in 1946 using some 10 engineers and 2 naval officers assigned by the Bureau.

By June 1947 the first phase of the study was completed by the General Electric group and a report was submitted which described a liquid-metal cooled pile. There had been no experimental work performed in conjunction with the study, and it was necessary to base the design largely on liquid-metal data collected at the Argonne National Laboratory at Chicago, and by the Bureau of Ships from other research contracts on sodium alloys as heat-transfer media. The major portion of the physics calculations for the pile was made, not by physicists, but by a few of the engineers who had shown particular aptitude for the work. With the completion of this study, it became evident that a full-scale program was needed to investigate the engineering phases of the heat transfer of liquid metals, and, in particular, sodium and sodium potassium alloy. A $2,250,000 contract for such a program was, therefore, entered into by the Bureau with the General Electric Co. At the same time the Atomic Energy Commission which had now taken over from the Manhattan project, agreed to spend $30,000 for the continued study of the Navy pile; this sum permits about two technical men to stay in the project for 1 year.

While the work I have just described was going on at Schenectady, the Power Pile Division at Oak Ridge was also engaged in the study of a gas-cooled pile for a land power plant. This study was completed in September 1947. The Atomic Energy Commission, after considering this study, decided that no such power plant should be built without an extensive survey of possible alternative piles. Since the Power Pile Division was thus left without a definite objective, the naval group at Oak Ridge urged them to turn to a study of a water-cooled pile for a submarine. This study was started with the approval of the Atomic Energy Commission.

Now, there is a danger in using the term "study" particularly when referring to a nuclear reactor. On the one hand, a study may involve the expenditure of thousands of man-days by experienced physicists and engineers, together with the conduct of all the necessary physical and engineering experiments to prove or disprove the validity of the design. This type of study was used for the design of the Hanford plutonium piles.

On the other hand, the study of the submarine pile which was conducted at General Electric, and the one now under way at Oak Ridge involve the efforts of but a handful of engineers, with practically no help from competent physicists, and with hardly any attendant experimental work. Obviously, a study of this type is but a "paper" study, and cannot be used as a basis for a detailed design or even for knowing whether a detailed design is worth undertaking. I stress this fact because to date this is the only type of study which has been made for submarine nuclear power plants. If I may be so bold as to venture an opinion, I would guess that less than 1 percent of the work which will ultimately be required to design a submarine plant has now been accomplished.

There is another point which I feel I must make clear to this audience, and that is that to date the Atomic Energy Commission has never recognized the submarine power pile as a project nor has it given official status or priority to such a pile. I mention this because the impression is abroad that considerable work is being done on a submarine pile and that it is a project which enjoys high priority.

Now what has the Bureau of Ships done to bring about the early design and construction of such a plant? Sometime ago I realized that the first essential step was to have the Chief of Naval Operations go on record as to the military necessity for such a plant. After full discussion with all interested naval activities, the Chief of Naval Operations, on December 5, 1947, advised the Secretary

of the Navy that the most secure means of carrying out an offensive submarine mission against an enemy is by the use of a *true* submarine; and, that in view of the strategic importance of a submarine having both high underwater speed and a very high submerged endurance, it was important that the Navy initiate action with a view to prompt development, design, and construction of a nuclear powered submarine. He also stated that he believed the development of such a submarine, if given sufficient emphasis, could be completed by the middle 1950's.

Finally, the Chief of Naval Operations made the following recommendations to the Secretary of the Navy:

(*a*) That the great strategic and tactical importance of a nuclear-powered submarine be brought to the attention of the Secretary of Defense and the Research and Development Board.

(*b*) That, pending action by the Research and Development Board, the Bureau of Ships and the Atomic Energy Commission work out a mutually agreeable method for prosecuting the design, development, and construction of a nuclear propulsion plant for a submarine.

The Secretary of the Navy approved the recommendations of the Chief of Naval Operations, and, at the same time, designated the Bureau of Ships as the naval agency for the design and development of the proposed nuclear power plant.

On January 20, 1948, the Bureau of Ships forwarded to the Atomic Energy Commission a detailed proposal for designing and constructing a nuclear power plant. The proposal emphasized these salient facts:

(*a*) The responsibility for the development of atomic power is, by law, vested in the Atomic Energy Commission.

(*b*) The responsibility of the Navy to have the best possible naval vessels to implement our national policy makes it mandatory that no time be lost in proceeding with the design of a submarine nuclear power plant.

(*c*) The problems to be solved are so intimately connected with both the Atomic Energy Commission and the Navy that neither activity can make separate engineering decisions regarding them, and the program must be coordinated in the closest possible manner between the Navy and the Atomic Energy Commission. The basis of the plan suggested by the Bureau was as follows:

(*a*) That the construction of an experimental submarine nuclear power plant be definitely contemplated.

(*b*) That the authority for this work be delegated to a single organization, working both for the Bureau of Ships and the Atomic Energy Commission.

(*c*) That facilities of the Atomic Energy Commission, the Bureau of Ships, and the Office of Naval Research be used to the fullest extent.

(*d*) That additional personnel be trained in order to reduce demands for personnel from atomic energy installations.

The plan also provided for considerable expansion of the studies now under way. This would involve extensive work on shielding, on materials, and on heat-transfer systems. Furthermore, the material which can be used in a reactor must not only possess the ordinary requisites of good engineering materials, such as strength at high temperatures, resistance to creep, etc., but they must, in addition, be able to withstand the intense radiation effects of the reactor.

This question of the relationship between the Bureau of Ships and the Atomic Energy Commission has not yet been settled. The problem has been considered by the General Advisory Committee to the Atomic Energy Commission and by the Research and Development Board. They came to the following general conclusions:

(*a*) A nuclear propulsion plant for a submarine is feasible.

(*b*) Such a plant is of great strategic importance.

(*c*) A liaison officer with suitable staff should be assigned by the Bureau of Ships to the Washington headquarters of the Atomic Energy Commission. He should maintain close liaison with all phases of the AEC reactor program which bear on nuclear propulsion, and he should be given a status commensurate with the great importance of the undertaking.

(*d*) That the Bureau, on the basis of reports from this liaison, undertake such engineering development as it deems necessary, utilizing industrial personnel and contractors for the purpose.

Now, if both the Atomic Energy Commission and the Bureau of Ships assign sufficiently high priority to this project, and prosecute it wholeheartedly, there is no foreseeable reason why we cannot have a nuclear-powered submarine in operation by the middle 1950's, as envisioned by the Chief of Naval Operations.

The problem is largely one that is susceptible to solution by engineering

methods, and to which industry can make significant and important contributions. For this reason it is essential that industry be brought realistically into the picture at once.

I am sure that this is in accord with the views of the Atomic Energy Commission, and, in this connection, I should like to quote from an article written by Mr. Lilienthal shortly after he became Chairman of the Atomic Energy Commission.

"The first step is for this Commission to develop a program that can enlist a broad variety of institutions, industrial and academic, and encourage them to operate under separate directions, and with their own separate slants. The Atomic Energy Commission should not become an atomic czar. It should not hold all the reins tightly, making all the decisions, and like any dictator, diligently covering up all its own mistakes. It must not be said that people working in this pioneering field are afraid to try out new ideas simply because there's a chance these ideas may not work. The Commission should have no place for scientists and industrial technicians who would rather do nothing than run the risk of making a mistake. That's the way of monopoly.

"Spreading the work among diverse groups is the first step away from the danger of centralization over atomic energy."

I thoroughly agree with these forthright and farsighted remarks of Mr. Lilienthal, and I am certain that if we follow the basic philosophy of decentralization, of using industry, and of operating under separate directions, and with separate slants, this project will be solved—and in the shortest possible time.

In conclusion, I would like to repeat that the design and development of a nuclear-power plant for a submarine is of utmost importance to the Navy and may be a decisive factor in a future war.

Such a design is technically feasible, and is almost entirely an engineering problem. When such a plant will be available depends almost entirely on the initiative and effort expended. To date, it has not yet been recognized as a project, and only a very small effort has been expended toward its accomplishment. Common prudence, and the dictates of national defense, make it mandatory that this situation be recognized, and that work be undertaken without delay. We should use all agencies, industrial as well as laboratory, that can contribute to the solution of this project so important to the Navy.

I sincerely hope that in the very near future, the Atomic Energy Commission, in accordance with the recommendations of the various committees and of the Research and Development Board, will establish the development of a nuclear-power plant for submarines as a formal project at high priority.

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22. ATOMIC ENERGY: HOW AND WHAT?

Remarks of Commissioner W. W. Waymack, United States Atomic Energy Commission, Before the Council on World Affairs, Cleveland, Ohio, April 2, 1948

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Come now to economic power. We don't have this yet. Estimates as to when it will come range from several years (on a very small scale) to several decades (on a large scale). The reasons why this is going to take time fall into two general groups. The first group consists of a set of engineering and technical obstacles that have to be overcome. The second reason is in economics—how to produce the power cheaply enough to compete.

The nuclear reactors (or atomic furnaces) now in existence produce some heat—those out at Hanford for making plutonium produce considerable. It is not enough for power purposes, not nearly enough. No nuclear reactor for power has yet been built. Several of them, designed as first approaches to that objective, have been designed and are being built or soon will be. It is certain that enough heat for the purpose can be produced—all anybody wants of it. But we come back to the fact that our advances haven't answered yet all the practical problems of reactor design and construction.

For illustration, every substance that goes into a power reactor must meet three requirements, two of which are entirely new. It must stand intense heat, really intense heat. It must not be affected by prolonged exposure to radiation (bombardment by subatomic particles). Such radiation inside a nuclear reactor is so much greater than the radiation from all the radium ever produced that any comparison is ridiculous. Such radiation does funny things to materials

that we have been familiar with. Third, any material that goes into a reactor must have the negative quality of not absorbing neutrons.

Other problems involved in power production include the question as to what you will use to absorb the heat within the reactor and transfer it into motion that generates electric current. Whatever is used for this purpose (usually it is called the coolant or heat transfer medium) must meet the requirements just listed. Maybe it will be some liquid metal. And the intense radioactivity must not be transferred along with the heat.

These problems can and will be solved. They cannot be solved all at once or in a jiffy. But is the pace of progress slower than it need be; is it slower than it would be but for defense considerations?

I mention to you, since Navy spokesmen have freely said so, that defense considerations make it desirable to develop usable power from nuclear reactors whether it is economic or not. The idea is that we might well want to drive a warship with such power, no matter how much it cost. This hardly looks like a case of national defense considerations having the effect, up to now, of delaying early development of power. Quite the contrary.

More generally, it seems to me that the notion about "delaying power development for peaceful uses" falls flat the moment one tries to imagine the circumstances if everything were tranquil in the world and there were no pressures internationally. Bear in mind that the new knowledge which we need to get, whether in basic science or in engineering, including the design and building of reactors, is substantially the same whether we are pressed by defense considerations or those of peaceful uses. It occurs to me that, as a matter of horse sense based on all experience, we should today be approaching all these problems at a more leisurely pace if the world were entirely serene. We should hardly be putting taxpayers' money into it at quite the present scale in such a case. I don't think we'd have anything like the present sense of urgency, the driving impatience for results. My guess is, frankly, that we wouldn't be getting ahead with respect to usable power as fast in such a situation as we now feel we must get ahead. I suggest that instead of being delayed the coming of usable power, though it can't be "just around the corner," is actually being expedited.

In short, I don't think it is provable that, everything considered, peaceful uses up to now have been delayed by defense needs.

Note that I do not say that development of peaceful applications could in no circumstances be impeded, but only that up to now I do not think they have been. And I think it would be a mistake indeed to lose sight of them, to fail to try to advance them consciously as fast as possible all the while.

I cannot take time here today to develop in any detail any of the three kinds of peaceful uses that I have listed as "now seeable." I have to some extent done that on other occasions. Enough printed material to give you an idea of the tremendous constructive potential is available. I hope all of you will get it, absorb it, and communicate it to others. I shall merely mention, as I have mentioned at other times, that very conservative men who are immersed in this have ventured that the economic gains from isotopes for research in agriculture alone might well repay us within a comparatively few years for our atomic energy development.

I would have you now face the unknown, so much greater with respect to developments implicit in the cracking of the atomic nucleus.

Reflect for a moment upon what has happened in the world as a result of what we may call the controlled release of chemical energy. I mean steam power and all that. Also, I mean gunpowder and dynamite and TNT. Remember that the whole so-called industrial revolution, including the factory system and the creation of wage-labor (the breakdown of the feudal system which tied people to land), our modern communications and all—all this stems primarily from the putting of chemical energy to men's work. And chemical energy is the kind we get from very minor rearrangements of atoms—as in letting oxygen atoms combine with carbon atoms in a fire under a boiler.

Suppose that you stood now at the beginning of *that* age. Suppose that you, knowing nothing of what was to come, but perceiving some first effects, were asked to tell what the eventual, total effect on the conditions of human living would be. Would your errors, as you tried to prophesy, have been errors of exaggeration or errors of underestimation?

Suppose, just to take one segment of this, that you were present at the moment when the first use of chemical energy in an internal combusion engine was made—the first crude use. Suppose that *then* you were asked to forecast the effect. Would you have foreseen aviation as it is today? Would you have guessed the

automobile, and what the automobile has brought about in America's highway systems, in the breaking down of farm isolation, in the substitution of the tractor for the horse, in changing our farm crop pattern, in creating our gigantic automotive industry and in making Detroit Detroit?

Similarly, if you had been present when the Hertzian waves were discovered, would you instantly have foreseen wireless and broadcast radio and radar and television—and the effect, whether cultural or something else, of radio in all our homes?

Bear in mind that, thinking solely of the magnitudes of energies, the energy released, atom for atom, when we merely *split* a uranium 235 nucleus is millions of times greater than the energy released by any kind of recombination of elements—such as when TNT goes off.

And the energy released in splitting the uranium atom is less than one-thousandth of the energy potential within the split nucleus.

Do you think it conceivable that, given a chance, man will not use this source of energy to his advantage? And if when we say "energy" we *must* think of power turning wheels, because that is habit with us, this may not be the half of it. It may not be the tenth. Who can be sure, really sure, that it will be the hundredth?

For this is a major, not a minor, advance in the knowledge of the nature of things.

The path that Democritus pointed out—and probably others long before him—is indeed the widening avenue on which mankind now travels. Destination unknown. It could be a place of real riches.

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23. REALISM AND FANTASY IN ATOMIC ENERGY

Remarks of Commissioner Sumner T. Pike, United States Atomic Energy Commission, before the annual meeting of the American Psychiatry Association, Washington, D. C., May 19, 1948

Since the first atomic weapon went off at Hiroshima the American public seems to have gone through several stages of reactions to atomic energy. These stages are, of course, not wholly separable and a good many of our citizens are still in the earlier ones, or even a combination of them, but there does seem to be some chronological continuity.

The first reaction was largely wonder or bewilderment with some tinge of fear, but in the next one fear definitely took charge. At this point a good many well intentioned groups actively tried to scare the pants off our citizenry in an attempt to insure some form of world government which would prevent future wars with a corollary use of atomic weapons. This "one world or none" attitude seems to me to have been much like our national prohibition experiment which was, as President Hoover said, "noble in purpose" but which didn't work. Terror by itself is not a very good motivation for even good causes.

In the third phase there was a pretty clear eyed estimate of the problem and some first-class people attempted to frame workable methods for both national and world control of this new energy. During this period we got the Acheson-Lilienthal report, the Baruch proposal to the United Nations and the act under which our Commission operates, the Atomic Engery Act of 1946.

Somewhere along this time atomic energy which had been thought of mostly as a material for bombs turned pseudo-scientific. The Buck Rogers and Sunday supplement school of science popularizers gave us automobiles and ships powered by uranium in sizes ranging from an aspirn tablet to a baking power can. I said the Sunday supplement school of writers. I am sorry to have to include quite a few people who most definitely ought to have known better. A former Assistant Secretary of War gave us on paper a bomb a thousand times bigger than the ones we used on Japan, and the head of a midwestern university went the military one better by developing also on paper a contraption which would wipe out half of the United States at one blow. Other people in other lines of endeavor, including the medical profession, have for reasons of their own from time to time issued scare statements which at least have succeeded in getting the authors' names into the headlines.

The next mood, the one in which we seem to be operating in today, is one of great disillusionment on the possibilities of forming an international agreement associated with the realization that there must be long, dreary periods of drudgery before some of the encouraging promises of atomic energy are to be realized, with

however exciting possibilities in almost every area of chemical, physical, or biological research.

Strong elements of some of the earlier moods and attitudes still remain in the minds of the American people. It isn't strange that this is so. The technological advance made in producing the atomic bomb, telescoped as it was under the necessities of war was probably the biggest single advance of its kind in such a short time. Apparently in a moment we excelled our best previous work by something like 17 million times. It is no wonder that our thinking has been left in the lurch. It is no wonder that most of us have real difficulty adjusting ourselves to the possible meanings of atomic energy.

The need, however, for clear thinking is obvious. Psychiatrists know probably better than any other group that fear is no foundation for intelligent thought and understanding. Fear is never on your side. It is always against you no matter who is frightened, you or the other fellow. It could really be dangerous to a democracy for fear to be so widespread that it developed into mass demoralization. Perhaps it would be even worse if it developed into mass escape thinking or fantasy. Probably no one can stand up under overriding fear for very long. The strong turn about, examine and reason in search of a way to overcome or eliminate the cause. The weak retreat somehow or other into the twilight of unreality, some of them to the point where they become customers of yours. If we cannot live with fear then we must somehow or other fill the void with useful information, such as understanding, comprehension and knowledge.

Now briefly, what are some of the facts about atomic energy as they appear today? First, the weapon is a fact, an impressive fact. At the moment this country has it. No one, and I really mean no one, not even Drew Pearson, can give definite assurances as to when some other nation may also have atomic weapons. For this country we will attempt, and I think successfully, to make better use of our stock in trade of fissionable materials by improvements in the design of the weapon.

Second, usable power from atomic energy is on the way. There is a sizable time factor involved here and several subsidiary but formidable problems have to be solved before net usable power can be obtained. Probably after that there will be another period before technical and engineering people can perfect designs and achieve economies to the point that atomic power can compete in everyday use with other sources of energy. Indeed, it may be that atomic power will merely fill several needs where present-day sources are thoroughly unsatisfactorily; but power is on the way and constant intelligent effort is being expended. Some of the difficulties we see may be solved by lucky breaks and shorten our time schedule. On the other hand, some difficulties not yet known to us may show up farther down the road and make the job more difficult. Only time can tell.

Third, the radioactive isotopes are here with us today. They are facts—present, usable, tangible facts—made at Oak Ridge, Tenn., and distributed to the world. The projects for their use in research in biology, physics, and chemistry, in agriculture and industry are expanding daily and if it were not for the pressing shortages of trained men and instruments and for our undeveloped techniques, their application would be expanding even more rapidly than it is now.

Working as we do somewhere in the middle of a multi-ringed circus, in our job of developing atomic energy as trustees for the American people, we get some views of the reactions of sections of the public to various phases of this enterprise.

The Commission itself it seems has some reactions of its own, and by Commission I not only mean the five men who head it but Commission and staff in general. We seem to have developed some emotional calluses, something I suppose in the same way that bank tellers get over their initial fright at handling large sums of money, or, as in almost every poker game, the players at some time or another take the attitude of, "Oh, hell, they are just chips" and proceed to do things either bold or foolish, or both, depending on how results turn out. The Commission itself occasionally relaxes into a jocular mood and some of the corniest jokes are received with the loudest laughter. I suppose you could say these are escape symptoms. On the other hand, we are constantly made to feel the immense responsibility we carry. Of course, as compensation, we frequently do have reason for excitement and exhilaration as some of the fascinating possibilities of research open up, and as, even at this early date, small bits and pieces of new and useful knowledge are uncovered by means of these tools.

In Congress there is intense interest in the development of our program. In fact, for the first time in history Congress has established a joint committee to keep in daily contact with an executive agency, and believe me, they do keep in contact with us. And we with them. You can tell that they, too, use the "escape device" once in a while. For instance, many Members of Congress appear greatly relieved when they move from the highly secret aspects of the atomic energy program to the unrestricted problems of town management or personnel administration.

The scientific world is, of course, intensely aware not only of what is going on in the nuclear field but of some of the new horizons that are being opened up. One sees what I believe is an unprecedented eagerness to foster research, each group in its own field. This has even overcome for most of them the natural reluctance and distaste to be associated with weapons in any way, although, of course, there are exceptions. There is an almost universal resentment toward the secrecy requirements because, after all, interchange of facts, thoughts, and ideas is essential to scientific advancement.

It is interesting to note, however, that the Commission depends most heavily on the scientists for defining within their own fields the areas which should be open to the world and those which should be kept under varying degrees of security. In this work they have turned out, as might be expected, to be just as human as the rest of us. While expressing resentment in general, each group in its own particular field has tended to be extremely cautious about recommending the release of information. This, I might say, causes the Commission both some concern and some amusement since it is commonly thought that only the military mind tends to keep everything top secret. The Commission is thinking of issuing a low but determined growl at some of our scientific personnel to see if we can't shake some more information—especially engineering information—out into the public view.

One of the really interesting phenomena in the scientific field has been the entrance of scientists into the political arena. From shrinking violets who refused to be quoted for the lay press, a good many of them have turned out to be mass publicists of no mean ability, and I see signs that some of them are liking it. They have made a real contribution to the public in our problems, both scientific and political.

In the military establishment the relations are better than one could reasonably have hoped when one remembers the hullabaloo which went on 2 years ago over the question of civilian or military control. We have just concluded a series of tests of atomic weapons out in the Pacific at Eniwetok which required the closest of perfected coordination between the Commission and all three branches of the military establishment with personnel numbering several thousand men living in rather close quarters in not too pleasant a climate. The testimony, both official and grapevine, is of as great a success of combined efforts of coordinated parts of Government as has ever been achieved. I think this concrete instance says more than words possibly could.

From industry the reactions are as mixed and varied as are the various elements which make up industry. Some large companies were reluctant to stay with anything of a warlike nature and withdrew. That attitude is easily understandable when you remember the "merchants of death" campaign of the last decade. In all of the companies, however, which had, or have a part in this vast undertaking, you see an attitude of high and sometimes fierce pride in the achievement, which really was magnificent. Some of the boys don't like very much the patent features of our act, and that is easily understandable because they do look unprecedented. Of course the subject is unprecedented and we have no real qualms about working out a pretty satisfactory relationship as time goes on.

In the press, periodicals and radio group of mass public information of course one sees all sorts of reactions. Naturally not many people in this area have the technical information to distinguish accurately between the true and the false so we have had many unintentionally misleading headlines. It is the tendency, also natural, to stress weapons and to play down news about peacetime advances. However, nobody realizes this better than the press group itself, and it has laid out a program of self education which bears fine promise. The willingness even to attempt such an ambitious program is an indication of the responsibility which the press feels toward the country in these uncertain times of wildly varying tensions. We also have, of course, in the press a tight little group which seems to think that if all the responsibility in the country, even including the Presidency, were turned over to the military our problems would be solved. This is a group which has a strong streak of adolescence running through both its own editorial policies and its circulation.

In the educational field, and this includes not only our conventional educational institutions, but many other civic organizations, clubs and societies, there is the almost universal desire to know the facts about this business. It is quite embarrassing to decline opportunities to speak and explain to responsible bodies in considerable communities the facts about the atomic energy enterprise, but if our Commission is going to get any work done, we do have to decline probably over 90 per cent of such requests. Most of us thought that the initial demand for Commission speakers was something like the desire to see the strange new animal in the zoo and would soon abate. It has, however, steadily increased. There is a large demand, and a demand which should be satisfied. Probably speaking isn't the right way to get at it. We hesitate to have the Commission take the main responsibility for issuing information because there is real danger that such a course eventually may be misinterpreted as propagandization.

At present with the assistance of the textbook and other publishers and various educational groups, we are attempting to work up a sort of a source book, plus a list of people all over the country who are able to explain the things which puzzle our citizens. This need must be filled, if they are to have any rational basis for deciding the many questions which will inevitably arise about this subject as far in the future as we can foresee. For high-school students, the National Association of Secondary School Principals has made a stab at filling this vacuum with the new booklet, Operation Atomic Vision.

The reactions which we see in the general public are of course extremely varied. There are, however, several familiar types. One is the Buck Rogers reaction. When do we get those cars which will run for our whole lifetime with one charge of a cubic inch of uranium? When do we get all that power so cheap that we will have our houses heated, our meals prepared and cooked, our floors swept, and in general all work done for us, even perhaps to the point of doing elbow bending for us? Two, the medical miracle of no more cancer, no more heart disease, no more arthritis, no more common colds. People love miracles and especially medical miracles. In the past few years we have had the sulfa drugs, penicillin, streptomycin, and I am sure other miracles will roll out pretty regularly. There seems something miraculous about atomic energy, and it seems quite probable that with the extreme delicacy of the research techniques permitted by use of the radioactive isotopes we will learn many things about the fundamentals of cell structure, growth, and metabolism which were previously unknowable and are still unknown, but let's not have any more medical miracles prematurely heralded in the public press.

But the largest segment of the population is the one which has responded with a sense of futility and with apathy. I suppose at all times in all countries and on all new questions this group makes up the majority. The problem of what to do about this group is puzzling. Maybe there is nothing to be done, but there always exists in that group those who will respond to stimuli; there are people who will by educational media be brought to a status of awareness, to where they will do things. One of our greatest puzzles is how to do that very thing, to do it decently, fairly, quickly, and efficiently.

Which brings us to the question of what can you and should you as psychiatrists do. Obviously some of you will have to do something.

Years ago the town of Gadsden, Ala., erected a monument to the cotton boll weevil which by destroying its cotton crops led the people to better methods of farming, and at the moment the oil industry is semiseriously considering a monument to one John L. Lewis who by his conduct of the coal industry has been the best salesman the oil people have ever had. It may be that on the same basis you will want to set up a monument to atomic energy for sending you a lot of customers.

Into a world that already had plenty of cause for tension and anxiety, there issued a new, very different force startlingly introduced by a tremendous bang and mass destruction. Perhaps you already have had patients whose anxieties have been aggravated by the existence of atomic energy. If you are faced with this it seems to me you have as great a responsibility as the people in education or in the press and radio to have the easily obtainable facts to correct misinformation, misunderstanding, and misconceptions that contribute to the upsetting complexes of some minds. You would then contribute toward preventing the sometimes fantastic distortion of available public knowledge about atomic energy.

I completely understand that psychiatrists as a whole are as busy doing their work and training others as any men can be. I think I understand that you have an inadequate number of men trained to handle the patients who are or should

be under your care. But I don't believe you have much choice as to whether or not you will take on an additional load. You really owe it to yourselves, to your profession, and to the people who consult you to know at least enough about the subject to cool off anyone who seems hysterical about atomic energy.

Beyond this additional complication injected into your everyday work, undoubtedly you will have an important part in the civilian defense program now being studied. If there is any group which can evolve measures needed to prevent or allay mass hysteria in case of national emergency, it seems to me it is this group. But in this so-called peace which is so much unlike a peace, it would seem only sensible to take steps to channel the unique abilities of the psychiatrists into a well aimed attack on the obvious ramifications of a situation which one of these days we may have to meet without warning. I say this quite diffidently, but it might be well for the security of the country if you would give it careful consideration.

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24. WHY MORALE SAGS AT OAK RIDGE

By Stephen White

[From New York Herald Tribune, May 24, 1948]

Oak Ridge, Tenn.—The Oak Ridge National Laboratory of the Atomic Energy Commission is the largest, and in some respects the most important, research institution that the A. E. C. maintains. Except for direct work on bomb manufacture, which is done exclusively at Los Alamos, N. M., Oak Ridge contributes to every phase of A. E. C. activity. The separation of isotopes in the huge gaseous diffusion plant here, and the availability in case of need of the equally huge electromagnetic plant, are guided by technical results achieved in these labbratories. Across the continent in Hanford, Wash., the administrators of the plant that produces plutonium look to Oak Ridge for technical advice. Work in biology and medicine, the preparation of isotopes for outside workers, studies on the use of nuclear energy for aircraft propulsion and on the use of nuclear energy for peace—all these are among the functions of Oak Ridge.

When the Manhattan Engineer District turned over its properties to the Atomic Energy Commission, Oak Ridge was perhaps in the best condition of the three major installations. Hanford was in the throes of transfer from Du Pont to General Electric; the exodus of first rate scientists from Los Alamos had left that city in a sink of low morale. Oak Ridge, too, had had its transfer and exodus, but it was none the less a going concern, headed by perhaps the most brilliant scientist to choose to remain with the A. E. C. and turning out first rate work.

But in the short space of a year Oak Ridge has become the biggest headache from which the A. E. C. suffers. The personnel of the laboratory express frank doubts that it can survive the blows that have been rained upon it. It may be that they exaggerate the severity of these blows, but the fact remains that it is the presence of these scientists that makes the Oak Ridge laboratories, as they make any laboratories. If the scientists, whether rightly or wrongly, find it impossible to do good work there, then no good work will be done.

This is not a threat by means of which the scientists hope to alter matters to fit their desires. It is an actuality. Morale is depressingly low. Scientists are leaving the A. E. C. in significant numbers, and a great many more are laying plans to leave. The A. E. C. in Washington, the administration in Oak Ridge and the technical directors at the laboratory make no attempt to minimize the gravity of the situation; they accept it as an established fact and are doing all they can to correct it before it is too late. Some are afraid it is already too late.

The origin of this unhappy situation is threefold. Oak Ridge is having labor trouble, inherited from the Manhattan Engineer District but only recently acute; it has been having since the beginning of the year policy trouble; it has been having since last August a good deal of trouble carrying out the security investigations ordered by the terms of the McMahon act, under which the A. E. C. operates.

To say that the labor trouble was inherited from the Manhattan District is not to lay blame on that organization. During the war unions were requested not to organize the installations of the A. E. C., and they complied. With the end of the war they clamored for rights. It was decided, presumably as the result of a high policy decision, to offer no handicaps to unionization of Oak Ridge, and to use experience gathered there as a precedent for further decisions.

This was done during a period when the contractors who actually operate Oak Ridge were constantly changing. There were threats of strikes as negotiations went along, but they were never acute. Then suddenly, this year, the affiliate of the Congress of Industrial Organizations which has bargaining rights for the Oak Ridge National Laboratory reached the conclusion that a strike threat was its only recourse to enforce its demands upon the Union Carbide and Carbon Company. There has been no strike as yet, but a government injunction which enforced an eighty-day period of negotiation will expire June 8. It is at least as likely that the strike will occur as that it will be prevented.

Such a strike, in itself, will be serious enough. It will cut off the flow of the information upon which, in the long run, the entire A. E. C. depends. It will be also, as most such strikes are, the precursor of strikes to come. Once a strike has been called, it is a good deal easier to call another.

Scientific personnel are not involved in the dispute. They belong to no union, and have no labor troubles. They will not be able to work, however, if the strike occurs, and the prospect of further strikes, and constant labor discord among their less skilled co-workers, will be no incentive to continue at work in Oak Ridge.

The labor dispute, it should be added, is not a simple one. The union previously had a contract with the Monsanto Chemical Company, which operated the plant before Union Carbide took over. Union Carbide, which also operates the gaseous diffusion plant, has offered a contract to the laboratory union which conforms, in general, to national Union Carbide policy—this seems beyond criticism. In some aspects, however, this offer represents a cutback from the Monsanto contract, and the union, not unnaturally, is in no mood to accept cutbacks.

The policy situation that shook the laboratories came up with shocking abruptness during the last weeks of December. Ever since the war ended, Oak Ridge has considered itself the leader in research that would lead to the peacetime use of atomic energy; the so-called power pile. The program had been set up by Dr. Eugene P. Wigner, of Princeton, one of the most respected physicists in the United States. It was proceeding, Oak Ridge believed, with all celerity.

Then, without warning, the A. E. C. decreed that the program be terminated. Power work, it was announced, would henceforth be centralized in the Argonne Laboratory, outside Chicago. Dr. Wigner's program was jettisoned. The scientists who were employed on it might be rehired by Argonne and might not; the A. E. C. would not bind Argonne's hands.

This struck at the roots of Oak Ridge. Men and women who had planned to make their careers there were told they would soon be jobless. Scientists in other divisions were distraught; their sections might be the next to go. The decision had been made without consulting Oak Ridge and the scientists remembered again that they alone, of all the major installations, are without representation on the General Advisory Committee to the A. E. C. Worst of all, there was no explanation of the move, beyond a half-hearted statement that it was considered desirable to centralize power research.

An outsider can not expect to determine the wisdom of the A. E. C. decision. The commission is so reluctant to release any information that might have a bearing on subjects like this one that it is impossible even to bring thought to bear on its decisions. For all any one can prove to the contrary, the power program at Oak Ridge may have been spiraling toward disaster when the announcement of its transfer was made. But this report is concerned with effects rather than causes, and the effect is known; it was outright demoralization of the laboratories.

Meanwhile, the scientists had still another matter with which to concern themselves. In August of last year, again with shocking abruptness, two scientists were suspended. The explanation was given that they were to be denied access to restricted information pending determination of their loyalty. They were not told what the charges were against them, and so far as they knew they were to be offered no opportunity to defend themselves against these unknown charges.

Such a procedure was not calculated to build morale, and appparently the commission hastily came to that conclusion. As suddenly as they were suspended, the two men were reinstated and the entire matter forgotten. But the fear that such action would recur was more than justified a few weeks ago, when two more suspensions (not against the same two men) were announced, and three other men were informed that there were charges against them.

The nature of the charges and the procedures have been given ample publicity in the last few days. It is well to repeat that the scientists have no quarrel with the procedure now, as they justifiably had in August. But the effect of

being called to account on items that are clearly flimsy, and upon occasions appear to be the mere repetition of malicious gossip, is a new and staggering blow to morale that was already scraping the ground.

Again it should be said that the decision to investigate the loyalty of the personnel at Oak Ridge is imposed upon the Atomic Energy Commission by the law under which it operates. It may be that action of exactly the type taken is necessary to root out potentially disloyal persons; whatever the enthusiasts on either side may say, there is room for two opinions on the subject.

What seems worthy of note, however, is that each of the decisions—on labor, on security, on policy—is having a bad effect on Oak Ridge. That is not a matter of opinion; it is a pure fact, accepted by all concerned and subject to check by any one who wishes to visit Oak Ridge.

It may be that each decision was an eminently correct one. If that is true, and each is pressed to the utmost, however, the A. E. C. may end up with a national laboratory that enjoys an entirely normal labor situation, a most enviable program and the utmost in security—and in which absolutely nothing is done. It does not seem that this is an admirable outcome; none the less, it is a possibility. If it comes, one will be able only to say that the A. E. C. may have acted with utter correctness in everything concerning Oak Ridge, but that it has emerged with a serious failure chalked up against it.

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25. SOME MILITARY AND COMMERCIAL ASPECTS OF ATOMIC ENERGY

Address by Rear Adm. William S. Parsons, U. S. N., Navy Director of Atomic Defense at meeting of Military Order of Foreign Wars of the United States, New York Commandery, at University Club, New York, N. Y., June 28, 1948

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A third illusion is that large-scale production of atomic energy for peaceful industrial use could be achieved in a few years if we could only rid ourselves of our obsession with making bombs. During the nearly 3 years since August 1945, some development and a certain amount of careful thinking have been devoted to this problem. The conclusions based on facts available in 1948 do not support any rosy predictions of cheap, abundant power from uranium and thorium in the foreseeable future. Atomic-power units for special applications like mobile generators in ships and aircraft, and stationary plants in which the primary purpose is to produce more plutonium or uranium, should be in sight in our lifetime.

Even if there were mountains of pure uranium oxide waiting to be mined with steam shovels there would still be major problems to be solved in the field of nuclear physics and chemistry and also metallurgy and thermodynamics before the atom could compete with coal and falling water as a source of industrial electric power. Actually there are no known mountains of high-grade uranium oxide ore; in fact, in most cases the ore content is so low that the energy expended in extracting the ore more than offsets any nuclear energy from fission of the hard-won atoms.

I realize that the atomic-energy picture I have painted is far from cheerful. But I feel that it is unfair to blame our troubles on the atom. Atomic energy is made possible by the law-abiding not the law-breaking habits of the uranium atom. Man could well ponder this little electrical system which answers the same signals in the same way, whether it is in a quiet laboratory or at the fiery center of an atomic bomb.

In our search for direct dividends from atomic fission, we may be too impatient. Ten years hence it may be apparent that the indirect benefits are much greater. Thus, radioactive isotopes might not cure cancer directly but their use might lead to knowledge which would permit us to deal with it effectively. Similarly, atomic power almost certainly will not of itself, make deserts bloom. But new discoveries in the field of photosynthesis, through use of tagged atoms, might in the long-range future, lead to controlled production of food. If this should happen, our grandchildren would think of present agriculture as dating in the Stone Age. Such an obviously benign result might even shake man out of his perversity and enable him to solve his problems in a manner more rational and less suicidal than the current vogue.

26. ATOMIC ENERGY COMMISSION NAMES CARLETON SHUGG DEPUTY GENERAL MANAGER: REALINES DUTIES OF HEADQUARTERS STAFF DIVISIONS

(United States Atomic Energy Commission, Washington 25, D. C., information for the press, No. 122, August 5, 1948)

The Atomic Energy Commission today announced the appointment of Carleton Shugg, now Manager of the Commission's operations at Hanford, as Deputy General Manager, and outlined certain new assignments of duties to staff divisions at the headquarters office in Washington.

Mr. Shugg will be succeeded at Hanford by Mr. Fred C. Schlemmer, of Chattanooga, Tenn., the Commission also announced. They will take over their new duties in September.

In the newly created position of Deputy General Manager, Mr. Shugg will coordinate and expedite the technical and scientific phases of the Commission's widespread operations.

Carroll L. Wilson, General Manager, commented that the new appointments will bring wider industrial experience and direction into the headquarters organization while continuing the high standard of management experience and competence at Hanford, the largest production and construction operation in the atomic-energy program. He stated also that the changes in assignment of headquarters staff duties will provide for more precise fixing of responsibility in each major phase of the program, a consolidation of the executive workload among the General Manager's principl assistants, and a simplification of structure of the organization of the Commission's principal office, which by law is located in Washington.

Mr. Shugg for the past year has managed the operations at Hanford, including the huge existing plutonium-production plant and its expansion through the largest single-construction program in the peacetime history of the United States. The contractor at Hanford is the General Electric Co., and Mr. Shugg has represented the Commission in all its dealings with the company.

Mr. Wilson said the Washington headquarters of the Commission will be reorganized on the basis of 18 months' experience in directing an industrial-type operation within the Government. As Mr. Wilson's deputy, Mr. Shugg will serve as chief executive for the technical operations of the Nation-wide program, leaving the General Manager greater freedom for the statutory requirements of his office.

"The Commission plan of operation, utilizing industrial and academic-type contractors for all production and research work, requires a very high type of management experience and executive ability," said Mr. Wilson. "Mr. Shugg's experience in the Navy, as a manufacturing executive and shipbuilder, and as Manager of the Commission's Hanford operations, qualify him unquestionably for the post of Deputy General Manager."

The new organization of the Washington office will be more directly alined with the fields of the Commission's major activities—research, reactor development, production, and military applications. Specific executive responsibility will be assigned to the operating heads of the organizational divisions, with coordination by the Deputy General Manager. The operation of facilities by contractors will continue as at present under the five managers of operations at New York, Oak Ridge, Chicago, Los Alamos, and Hanford.

The field of production will encompass acquisition of raw materials; processing of feed materials for the production plants; the manufacture in the Commission's plants of fissionable materials and in other plants of special materials required in the program, and the construction program under way at AEC installations.

All phases of the military applications of atomic energy—the research, development, production, and testing of weapons—continue in one program with a single program head.

All reactor-development work will be consolidated into one program, including the engineering phases of chemical separations processes, waste disposal, and nuclear-power development work both for stationary generating plants and for propulsion purposes. The development of reactors for the expanded and more efficient production of fissionable materials is part of this program.

All phases of research in the field of atomic energy—including medicine, biology, and the physical sciences—will be grouped in a single program. Under one program head, a director for medicine and biology and a director for re-

search in the physical sciences will coordinate and supervise the programs in their respective fields.

The changes in oganization will place greater responsibility on the program directors, will reduce the number of persons reporting to the General Manager, and will insure more flexibility of management of projects carried out by contract-operators of atomic-energy facilities.

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27. SITE NEAR SCHENECTADY CHOSEN FOR NEW ATOMIC POWER REACTOR

(United States Atomic Energy Commission, Washington 25, D. C., information for the press No. 130, September 23, 1948)

SCHENECTADY, N. Y., September 24.—The United States Atomic Energy Commission announced here today that it would acquire 4,500 acres of land in Saratoga County, N. Y., as the location of an experimental atomic power plant for studies of the generation of electric power from nuclear energy.

The plant will be part of the facilities of the Knolls Atomic Power Laboratory, operated for the Commission by the General Electric Co., at Schenectady. The Army engineers will serve as agents of the Commission in the acquisition of the new site.

Preliminary surveys indicate there are about 30 families in the area selected. Construction schedules will make it possible to give the residents of the area from 6 to 18 months in which to find new homes and move. None will be required to move immediately and care will be taken to give adequate notice to all families. The exact limits of the area have not been determined, but the Army engineers will proceed with negotiations at once in order to give the residents as much time as possible to make other arrangements.

L. E. Johnston, manager of AEC Schenectady operations, said assistance would be given to any families desiring it, and that every effort would be made by the Commission and by the General Electric Co. as contractor to minimize the effects of the Government's acquisition of the land.

Dr. C. G. Suits, vice president and director of research for General Electric, said that the nuclear reactor, the heart of an atomic power plant, would be quite different from the production reactors at the Commission's Hanford works in the State of Washington. The Hanford plant, now operated by GE, was built during the war for the sole purpose of making plutonium for military purposes and generates no useful power.

The new Knolls reactor is one of two now being designed especially for the study of high temperature operation and the production of power. A different type of reactor but for a similar purpose is planned at the Commission's Argonne National Laboratory near Chicago. The design of both these reactors is directed to the problem of power generation by nuclear fission but by different methods, and both are expected to yield important data leading ultimately to the design of reactors which will produce power on a practical scale. They will also be valuable in solving some of the problems involved in "breeding" nuclear fuel.

In the operation of a nuclear reactor, the fuel consumed consists of fissionable material which produces heat for conversion into power. If the so-called breeding process works as scientists have reason to expect, the reactor will more than replenish the fuel consumed in operation. In addition to producing heat, a breeder-type reactor would convert nonfissionable uranimum 238 into new fissionable matter.

The Knolls Atomic Power Laboratory was established in November 1946 to carry on research in all phases of atomic power development. It is located on a site of some 180 acres obtained from the General Electric Co. and adjoining the company's own fundamental general research facilities. This site is not large enough to accommodate the new reactor and generating system.

The new site was selected after extensive surveys of the entire area and was recommended to the Commission by a joint AEC-GE committee, and after the Army engineers had determined that no Government-owned land in the Schenectady area was suitable for location of the reactor.

The area for the new installation, upon which preliminary construction work will begin this fall, lies near West Milton, 10 miles west of Saratoga Springs and 15 miles northeast of Amsterdam. It is about 18 miles north of the Knolls Atomic Power Laboratory facilities.

Choice of the location was guided by the necessity that the project be near enough to Schenectady to permit ready and frequent use of the extensive technical

and scientific resources of the plant and laboratories of the General Electric Co. Other important considerations in selection of the site were availability of water and power and suitability of underlying formations for the installation of heavy concrete structures.

The size of the acreage to be acquired was determined by safety and security requirements and the need to provide freedom of laboratory action in carrying out experimental work, including the handling of radioactive materials. Additional advantages of the site are that it will require the displacement of fewer people and involve land of less agricultural productivity than other locations considered.

Operation of the reactor will involve the production and handling of radioactive materials, carried out in a closed cycle process that does not permit the escape of radioactive liquids or dust. In designing of the Knolls reactor, GE scientists and engineers have available the results of more than 5 years of experience of reactor operation carried on in various places in the United States. Experience in handling radioactive materials at many installations of AEC and nongovernmental institutions will be utilized on this project.

In authorizing acquisition of this site, the Commission has considered the dangers which might be created by a serious accident to the reactor. It is not possible to have a bomb-like explosion. The rare type of accident which may create off-site hazards is in the nature of major damage to the reactor resulting from sabotage, severe earthquake, or the remote possibility of simultaneous failure of all safeguards and control mechanisms.

In view of the remoteness of these contingencies and the emphasis on safety measures to be built into the plant, the Commission and the company have concluded, on the basis of careful studies by their respective staffs together with expert consultants, that the establishment of the plant on this site is fully justified. Throughout the development of detailed designs, however, and during construction the work will be under continuing review, with testing of safety mechanisms prior to installation and final reexamination of the entire plant before the reactor is actually put into operation.

In recognition of the fact that atomic power plants must be so constructed as eventually to permit their operation in populous areas, a first requirement of design is to assure complete and adequate control at all times. Studies of control mechanisms and safety measures have been under way at the Knolls Atomic Power Laboratory for 2 years. A major objective of the design work has been to make sabotage so difficult as to effectively remove sabotage as a threat to continued operation of the reactor.

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28. THE PEACEFUL ATOM

Remarks of Lewis L. Strauss, Member, United States Atomic Energy Commission, Before the University of New Hampshire, October 9, 1948

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First, we may choose to consider atomic power. Since the reaction of neutrons upon nuclei, within the atomic pile produces heat and since the rate of the reaction within the pile can be quite accurately controlled and the production of heat made uniform, it seems clear that all that is needed is a transfer of the heat to a suitable engine to derive useful work. A great many people jumped to the instant and understandable conclusion a couple of years ago that atomic energy for power was just around the corner.

But it isn't that simple. True, we can obtain heat from the pile but it is heat associated with intense and deadly radioactivity. No heat transfer or useful engine has yet been contrived which can be operated and serviced under such lethal conditions. The problem will surely be solved, but it will require perhaps a number of years of hard work on the metallurgy, chemistry, and mechanics of very new techniques. These techniques involve perhaps, among other items, the handling of liquid metals for cooling, difficult chemical problems of separating impurities from the atomic fuel, and methods for protecting those who must work near and tend these mighty machines. This development will take considerably more time than the Sunday supplements once led us to believe.

When the day does dawn for atomic power, it will probably supplement rather than replace other forms of power. Its obvious value to remote areas where neither water power, coal nor oil exist and where transportation is difficult, is apparent. In time even, its cost may become so low as to give real competition to other power sources, but it looks today rather like a legacy to

our children or even our grandchildren than that we who are here today shall make our own breakfast toast and coffee with electricity generated by the heat of an atomic pile.

It is true that piles might conceivably be used at a considerably earlier date to power warships or submarines where carrying great weights of shielding material to protect personnel from radiation would not be economically barred, and where the presumption of expendability, inherent in war material, would make it possible to accept the difficulty in servicing or effecting repairs as unimportant.

It has also been suggested that there is the possibility of using "packaged power" in the form of material placed in the pile where it becomes radioactive and then taken out and used as a sort of storage battery. But such small units would also require shielding to protect personnel against radiation, would be relatively costly and their rate of heat production could not be controlled as they would gradually run down in compliance with the natural laws governing radioactive decay.

Nevertheless, despite its difficulty, it is inevitable that power in usable form and in great amounts will be obtained from nuclear sources—perhaps in some quite direct manner without the intervention of the engines we today envisage. Perhaps we have not divorced our thinking from the machines with which we have long been familiar—just as we equipped the first automobile with carriage lamps and a dashboard. Cheap and abundant atomic power can confer upon us benefits so obvious that an attempt to catalog them would be endless.

Next we may consider that byproducts of power, or more properly speaking, of the piles in which power is produced—the radioactive isotopes of the elements. As is so often the case in industry, these byproducts may be more important than the prime product itself. We know of certain great areas today in which they are useful. Dr. Arthur Compton once commented that, "Fifty years ago it was evident that X-rays were useful for seeing through objects—such as the human body—which are opaque to ordinary light. It could not be predicted that X-rays would become a powerful weapon in the fight against cancer or that researches made possible by X-rays would reveal the electron and, with it, give us the radio and a host of electronic devices. Such unforeseen developments are the result of every great discovery. *It would therefore be surprising*," he continued, "*if the most important consequences of the release of atomic energy are not in directions as yet unpredictable.*"

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29. RESEARCH AND THE DEVELOPMENT OF ATOMIC ENERGY

Remarks by Robert F. Bacher, Member, United States Atomic Energy Commission, at the November 18, 1948, Meeting of the Washington (D. C.) Academy of Sciences

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The requirements of nuclear reactors have posed many interesting and difficult problems. Due to their unusual ability to absorb neutrons, it has become necessary to separate rather completely some elements from various materials with which they are usually found and in which they have frequently appeared as impurities due to their similar chemical properties. In some cases it has been necessary to reduce the content of such impurities in reactor materials to a fraction of a part per million. The effects of radiation upon materials in nuclear reactors have prompted a vigorous investigation of the solid state characteristics of certain materials. The whole subject of the solid state is, indeed, a difficult one, and the radiation effects upon materials are today only very incompletely understood. These effects constitute one of the major problems in reactor development and some further basic understanding will certainly be necessary in the course of this development. In addition, the requirements of reactors have led to the development of several new metals which have not been used before due to their difficulty in preparation but which may prove to be the structural materials of the future since they show surprisingly good nuclear properties.

The development of nuclear reactors is a subject which is just beginning to come into its own. At the end of the war, the optimism about the development of atomic power struck everywhere, and the technical difficulties were only just beginning to be understood. For example, radiation effects upon materials in reactors had been anticipated, but the seriousness of these radiation effects and

the difficulties which they might lead to were only partially foreseen. Radiation effects soon proved to be a reality, and the difficulties to which they led were serious. It became necessary to backtrack considerably in reactor development in order to take account of these radiation effects.

In addition, the chemical problems of reprocessing nuclear fuel, or of extracting plutonium from irradiated uranium, have proved to be a major headache. These chemical processes are costly, complicated, and involve tremendous outlays in plant. Disposal of the radioactive wastes obtained from these chemical plants has proved to be extremely difficult.

During the past 2 years, considerable progress has been made in the development of new chemical processes which may prove to be more efficient and which may help in the problem of disposal of radioactive products from the fission process. The disposal of these products which have sometimes been referred to by the uneuphonious name of atomic garbage is much more difficult than the disposal of ordinary industrial wastes.

These hurdles in the development of nuclear reactors seem now to have been partially cleared, but we can by no means conclude that the production of electrical power from nuclear reactors is technically feasible, let alone economically feasible.

It seems very likely today that new technical developments will make the production of electrical power from nuclear reactors technically feasible. But exactly how complicated such a plant will be and what its efficiency may be are points which are pretty much unknown. There are, indeed, whole sections of this work which are unexplored. For example, we know that the efficiency of a heat engine depends upon the difference in temperature of the thermal cycle. Nuclear reactors today operate at relatively low temperatures, and, thus, the temperature difference measured on an absolute scale is indeed small, and the efficiency necessarily low. In order to achieve higher efficiency, it will be necessary to operate nuclear reactors at much higher temperatures. Such operation involves many technical developments, some of which may prove to be desirable for other reasons as well, but much new work is necessary.

The question of economic feasibility is one on which we can only speculate today. It is true that various papers have been written upon this subject, but it seems most unlikely that the question of economic feasibility can be sensibly commented upon until the technical situation is considerably clearer. We should remember, however, that the course of any new development, once its outlines have been clarified, is always to simplify and thus cheapen the process. Although the development of electrical power from nuclear reactors today looks complicated and questionable from the economic standpoint, we can expect the developments in the future will make this development considerably more favorable. But in spite of this, it is far too early to make any predictions about the economic feasibility of atomic power.

On the technical side, the situation is much more promising but the developments are going to take some time. On a demonstration basis, electrical power will probably be developed from a nuclear reactor within the next 2 years. Within the next 8 to 10 years there should probably exist a prototype of a nuclear reactor for the production of electrical power in quantity. This unit, of course, will be preceded by smaller units, and two of these are now being designed and will soon be under construction, one at the Argonne National Laboratory and the other at the Knolls Atomic Power Laboratory near Schenectady.

Of course, the whole development of economic electrical power from nuclear reactors is but one aspect of reactor development. For some purposes, such as the propulsion of a ship, the nuclear reactor has peculiar advantages from the fuel standpoint. Here, of course, the question of size, weight, and complexity of the nuclear reactor and its auxiliary equipment are of paramount importance. While no reactor, operating at the temperature presently used, could possibly prove to be a useful source of power for such a purpose, the use of higher temperatures may reasonably be expected to lead, in the not too distant future, to reactors which are suitable for this purpose. Whether or not the characteristics of such reactors are such that they will prove to be useful sources for ship or submarine propulsion will have to await the outcome of the development work. At the present moment, the prospects in this direction look favorable and it seems likely that this will be the first application of a mobile nuclear reactor.

Many people have speculated upon the possibility of driving an aircraft by a nuclear reactor. There are, of course, many intriguing possibilities due to the extraordinarily large energy content per pound of purified nuclear fuel. Unfortunately, nuclear reactors as we now know them are heavy. In particular, the shields for protection from the penetrating radiations produced inside must

be very thick and heavy. Furthermore, the temperatures needed for aircraft nuclear reactors will probably need to be much higher than those which might be tolerated for driving a ship. In short, the problems here seem to be much more difficult.

The other day I read in a newspaper that someone had said that the theoretical work for the construction of a nuclear-powered aircraft was 99 percent complete. Probably he was misquoted, since there are certainly some important scientific problems yet to be solved. But the development of a nuclear-powered aircraft is primarily a technical and engineering problem—not a scientific one. Whether such a development will prove to be feasible can only be determined if a very great amount of new technical work is done.

In this connection it is interesting to note that the B–29 which was first used in combat in the later stages of the war was being designed prior to the discovery of nuclear fission. It took just about the same time to go from the discovery of nuclear fission through the production of experimental, pilot plant, and production chain reactors, through the extraction of purified fissionable material to the development and construction of the atomic bomb that it took to proceed from the design of the B–29 to its actual use. This is by no means due to any lack of ingenuity and industry on the part of airplane manufacturers, but rather to the enormous complexity of the technical and construction problems which must be solved to make an airplane or airplane engine. We cannot expect the nuclear-powered aircraft to appear in the next few years even if further work does indicate that it is feasible.

One of the most exciting prospects in the development of nuclear reactors is the possibility that one may be able to consume fissionable material, obtaining energy from this process, and at the same time utilize the neutrons thus produced to generate a larger amount of fissionable material than was destroyed. This subject is now being actively pursued. Whether or not it will be possible to achieve is not yet clear. In order to be practical, it will also be necessary to develop highly efficient chemical treatment of the nuclear fuel which from time to time must be reprocessed. It is a very intriguing possibility, and since the amount of new material which can be produced will depend both upon the intrinsic rate of production in the reactor and the amount of fissionable material thus committed, our stock of fissionable material may prove to be an even more precious possession than it seems today.

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30. PRIVATE INDUSTRY AND THE PUBLIC ATOM

Address of David E. Lilienthal, Chairman, United States Atomic Energy Commission, Before the New England Council, Boston, Mass., November 19, 1948

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There is today no international control. Nor is this likely in the near future. So we are forced to maintain a shield of secrecy about vital parts of this huge business. Now, of course, secrecy about an industrial process is not unheard of in business. But the stakes of secrecy were never as high as they are in this undertaking. And never in industrial competition was it ever worth as much to a competitor to uncover secret knowledge as in this international rivalry.

To adapt our ordinary American formula of the widest competition in ideas and development, to an area where considerable secrecy is obviously necessary is not a simple problem. The solution won't be found in any such suggestion as the one seriously made a little while ago that we should put into one neatly tied bundle what are called our military research and technical knowledge, keep that in military hands and secret; and then turn what is called the industrial side over to private industry for competitive development. The facts make it clear that such a quick-and-easy answer is nonsense, for there can simply be no such neat packages. How to make and operate machinery to separate the atoms of uranium having different atomic weights—the knowledge that is the basis of the huge plant at Oak Ridge—is certainly industrial knowledge. But it is the very sort of knowledge that must be held secret as long as possible. For it is that industrial knowledge that enables us to make uranium–235 an ingredient of a military weapon. The same thing is true in our current work in the development of entirely new processes, and the improvement of existing

ones. It applies, too, to the design and development of machines to extract useful power from the enormous heat engendered by the splitting of uranium atoms in an atomic furnace or as it is usually called, a nuclear reactor.

Our task would be far easier if the facts were otherwise; if for example the design and development of an atomic furnace to produce useful power—something that is certain to come—could be turned over to the open competition-of-ideas system that has worked so well in the past. The more minds at work on that problem, publicly competing with each other, the faster the country would get a new source of useful energy. I have not the slightest doubt about that. But the knowledge and know-how required to develop such a useful power reactor is the kind of information and skill our international competitors most need to have, for military reasons.

From all these facts does it follow that the great benefits to atomic development that private industry and business can contribute must be denied to us? Does it follow that there are no areas for private investment of funds—risk funds—no way to call upon the diverse talents of American competitive industry? Are there no ways by which American industry can participate in the industrial aspects of this huge project?

Clearly the usual industrial and business formula is not applicable, certainly not at this juncture in world events, and probably never will be completely. This undertaking is so close to issues of life and death for our country that the kind of development, the amount of manpower and funds, the direction and the pace of the development—these must of necessity be determined not by private considerations but considerations of the public security. Under our Constitution such decisions are entrusted to Government responsible to the people as a whole.

But just because the usual formula cannot be applied, the Commission does not believe that it cannot be so modified and adapted as to secure many of its proven benefits to the country and to industry.

Furthermore, areas will appear, from time to time that can be separated off and left to the usual forces of the competitive system. But this process—the gradual denationalization of the atom—must be on a case-by-case basis.

There already appear to be at least three areas in this undertaking where private business can operate in substantially the usual manner. This the Commission has encouraged, with reassuring results.

The first of these is in the mining, milling, and processing of uranium ores into high-grade concentrates, within this country. The Commission has acted here on the assumption that the usual incentives of private profit, and risk of loss, and private initiative should operate to do this part of the job. No essentially new processes and no large chunk of information that needed to be kept secret were involved. This appears to be working well: new capital is being invested, there is great activity on the Colorado plateau, where uranium is found.

A second area for private development is in the preparation of radioactive tracer compounds, and their use in private industrial laboratories and in process control. Here again we have encouraged private investment and private development, and have instituted courses to train the employees of private companies to use these materials safely and effectively. As industry finds more and more practical use for these tracers a rather considerable business will undoubtedly grow up.

A third area is in the manufacture and maintenance of radiation detection instruments. During the war these instruments were chiefly supplied by a single concern or by direct Government production. But it has been our view that here too is an area where the widest competition should be encouraged, based on private investment and direction. Today some 40 concerns, all still rather small in size, are making these instruments. The business will grow and better instruments will be developed as the market expands, in industry, in hospitals, in agricultural experiment stations, in civil defense, and so on.

When we come to the design and the operation of reactors that produce fissionable material—such as those atom-busters now operating at Oak Ridge and Hanford—and the design and development of reactors for useful power the difficulties really begin. But they are not insuperable. True, the ownership and full responsibility for such activities cannot be delegated to private hands.

It is also true that a case could be made that this development work and the operation of these plants should be by the Government directly. I have no doubt that if given flexibility and adequate authority a Government agency could do these jobs and do them effectively.

But there is a better course and this is the one the Commission has adopted.

The actual operations of the Oak Ridge and Hanford plants the Commission

has delegated to two leading private industrial firms, General Electric Co., and Carbide & Carbon Chemicals Corp. Other parts of this huge enterprise have been delegated in similar fashion. In this way the country has drawn upon and benefits by the experience and industrial skills of leading private corporations.

But this delegation to private industry is not the usual pattern of American industrial development, and I do not want to be understood to mean that it is. For these private firms take no financial risks. Neither do they make any profit, in the commercial sense. They do make an investment in people, their employees. These people become proficient in a new technology, gain new ideas adaptable to their companies' processes or products. From their new skills, in time they can expect a return. Other incentives apart from profit do exist, among them the incentives that strongly motivate men in pioneering a new field. But the incentive of relatively immediate profit is lacking. We have not yet been able to devise other incentives that fully take its place.

The worrisome and heavy responsibility for security and secrecy the Commission cannot and does not delegate. Decisions as to general course of the venture, expansion or contraction, and such major questions of policy as these continue to be vested in the Commission which is held responsible for the results by the Congress, the President, and the public.

In the development of wholly new processes—such as a new chemical process for the recovery of plutonium and uranium from used fuel material upon which great effort and huge sums are now being expended—the Commission is able to come somewhat closer to the competition-of-ideas thesis. In this one case (in addition to General Electric) the following leading chemical firms of the country are all working on the problem with their own personnel: Standard Oil Development Co., Carbide & Carbon Chemicals Corp., Kellex Corp., Blaw-Knox Co., Monsanto Chemical Co., and Dow Chemical Co. Other chemical companies will be brought in later, as this work proceeds.

As to the design and development of reactors for the production of useful power the Commission is directing an extensive program in Commission-owned facilities, chiefly at the Argonne Laboratory near Chicago, and the new Knolls Atomic Power Laboratory at the GE works near Schenectady.

At present there are atomic reactors operating at Los Alamos, N. Mex.; at Oak Ridge, Tenn.; at the Argonne, Chicago; and at Hanford, Wash. Another reactor to be used for research purposes will be started up early next year at the Commission's Brookhaven National Laboratory on Long Island. Two new reactors for power are now well along in the design stage. Actual construction of the reactor to be located at the Knolls Laboratory near Schenectady will start early next year. Design for a third reactor to be used for the study of reactors themselves is nearly completed. Preliminary planning on still other reactors such as for ships and submarines has begun.

This is a Commission-financed and Commission-directed program. No one firm is equipped with sufficient men, money, or knowledge to take on the responsibility for this work. But industry will send men to the establishments, men who will stay for periods of time and join in the actual work. In this way, firms will be able to keep up with developments of possible use in their own industries. At the same time, the laboratories will benefit by the new and fresh ideas these men may bring to the job.

No private concern has yet come forward with a proposal to build a reactor at the expense of the company. There is a good reason for this. These reactors are very expensive experiments. To the cost of the structure itself must be added the expense involved in necessary safety and health measures, in heat transfer and chemical processing facilities, in people to do the operating and maintenance and research, and in the buildings and facilities needed to maintain the people. Altogether the cost of a reactor runs to something like $50 million. The prospect of a return is remote in time, and the money risk is great.

No private capital in these amounts is forthcoming or is likely to be forthcoming in the next decade even if security considerations made it possible to turn such development over to private hands. This is understandable. Much of the knowledge necessary for the development of useful reactors has yet to be acquired in the laboratory. To work out the many-sided problems involved in this development we must draw upon a great variety of scientific and engineering talent, the physicist, the metallurgist, the chemist, and many kinds of engineers. Such a corps of research and development men, including engineers from industry, is being brought together to work in concert, and we expect that leading

industrial firms will, as time goes on, become part of this development in a manner analogous to that employed in the case of process development.

What I have tried to present today you will recognize is but the barest outline; but I hope it is only the beginning of a discussion on other occasions and by others in which additional facts and specific activities of the Commission can be examined in greater detail.

I have tried to describe the basic industrial policies of the Atomic Energy Commission, to summarize some of the salient facts that shape that policy, and in the briefest manner to refer to actual programs intended to further those policies now under way or in process of launching.

These are matters that require the widest possible public discussion. The Commission has been aided greatly by the counsel of advisory committees of experienced men in a number of fields of industry and engineering. But if our course in putting the atom to work is to be sound and fruitful of the best results, we need counsel and criticism and discussion from the whole of American business and industry.

These problems are tough. No question about that. But Americans have faced tough questions before. There is nothing in congressional policy or Commission policy that may not be changed, if a better course can be developed by public discussion. We are sure that there is room for improvement both as to policy and in the way we are carrying it out.

The stakes are very great indeed. If we all put our heads together, we will find a practical way to make our new knowledge of the atom advance American industry, and enhance the whole of American life.

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31. WHY DON'T WE DO SOMETHING ABOUT ATOMIC POWER DEVELOPMENT?

By Andrew W. Kramer, Editor, Power Generation

(From Power Generation, December 1948. Reprinted by permission the copyright owner.)

Engineers, as a class, are not blessed with a superabundance of imagination. There are exceptions of course, but ask the average engineer whether a certain course of action or a certain scheme is feasible and he will immediately get out his slide rule and begin to establish a number of safe assumptions. If he does give you an answer it will be on the safe side with plenty of margin for uncertainties. The engineer, in other words, plays a safe bet, necessarily so, because that is the only way he can keep his job; he is not paid to take chances.

However desirable this conservative quality may be in dealing with everyday engineering problems it has its shortcomings in the projection and development of new scientific discoveries. History is replete with the mistaken predictions of those who knew it couldn't be done. It takes a more daring, a more fanciful type of mind than the slide rule thinking of the engineer to see beyond the immediate engineering obstacles which inevitably stand in the way of any new development. The really great engineers, indeed, are those who possess imagination as well as engineering skill.

The development of the atomic bomb took imagination—the imagination of men like Fermi, Einstein, Lawrence, Conant, and Hutchins. Hahn and Strassman had demonstrated the phenomenon of nuclear fission in 1938, but no scientist in the world at that time had any evidence that this nuclear fission could be made to sustain a chain reaction. Yet in March 1939, Enrico Fermi approached the United States Navy Department and pointed out the possibilities of uranium both as a source of power and as a source of explosive reactions. This took both imagination and courage—courage of one's convictions.

We all know what happened as a result of Fermi's initiative; how, after 5 years of unremitting effort and the expenditure of $2 billions, we produced the atomic bomb but only those very close to the project, those concerned with overcoming the all but insuperable obstacles that arose all along the way, know how great a part sheer vision and imagination played in attaining final success.

Engineers, of course, did most of the work and they did a magnificent job. There is no intention here to detract in any way from the great engineering accomplishments of the thousands of engineers who actually designed and constructed the great plants at Oak Ridge and at Hanford, but over and above all were the Lawrences, the Fermis, the Conants, and the Comptons—the men who staked their reputations and hundreds of millions of dollars on ultimate success. It

is to their everlasting credit not so much that they achieved this success but that they had the vision and the courage to go ahead in face of apparently insurmountable obstacles.

Over 3 years have passed since the atomic bombs were exploded over Hiroshima and Nagasaki; exactly 6 years have passed since the first nuclear reactor went into operation at the University of Chicago and while there has been great discussion regarding the use of atomic energy as a weapon in war, there has been little active interest in the development of atomic power. True, several utility groups have been cooperating in various research programs[1] and at the present time power reactors are being constructed at several of the AEC laboratories, but there has been no large-scale interest on the part of the utilities in the actual development of nuclear power plants. With the extremely narrow margin between installed generating capacity and the steadily growing electric load, it would seem that the utilities would make a much more concerted effort to develop this new great source of energy.

It is understandable, of course, that the utilities' needs are immediate and that even under most favorable conditions, large-scale atomic power development is a decade or more away but this is not the reason for the lack of interest. Nor is it lack of progressive spirit. No one who has occasion to visit modern utility plants can accuse the utilities of not being progressive. Their progressive tendencies, however, are along conventional lines.

The chief reason for the utilities' apathy toward atomic power development, I feel, lies in the lack of imagination on the part of engineering executives who direct development in the industry. They seem to be much more conscious of the obstacles in the way of atomic development than they are of the possibilities.

Has there ever been a more exciting idea in the field of power generation than the possibility of operating say a 70,000-kilowatt power plant on just 2 ounces of fuel a day? That idea alone, it would seem, should stimulate interest to the point where no obstacle would be seriously considered. There are many other fascinating prospects in atomic power, however. The possibility of building plants anywhere regardless of the proximity of water or fuel resources, the complete absence of smoke, the possibility of designing much smaller plants, of putting them underground, these to mention only a few. Over and above all is the matter of unlimited fuel supply.

HOW MUCH URANIUM IS THERE?

This question about the supply of fissionable fuel is one that is most frequently asked by engineers. Unfortunately, uranium has for many years been regarded as a rare element. In a press interview shortly after the atomic bombs were dropped on Japan, no less an authority than Dr. R. A. Millikan pointed out that uranium was a rare material and that that ruled it out as a source of atomic energy for power. Actually, uranium is not a rare element. It is widely scattered throughout the earth's surface but compared to other rather common elements it is relatively abundant. Before 1941 it was known that there were rich commercial deposits of at least 50,000 tons. These, at present, are the sources of supply for the Hanford plants and other piles that have been constructed in various places throughout the world. While these rich deposits will be adequate to supply the world's needs for some time to come, there is no valid reason why the more scattered lean deposits of fissionable material should not be used. The commercial value of uranium is high enough to warrant reasonably high extraction and refining costs. Estimates have been made that the earth's crust contains 5 trillion (5×10^{12}) tons of uranium and 15 trillion (15×10^{12}) tons of thorium. As indicated by Dr. C. Rogers McCullough, of the Monsanto Chemical Co., in a recent address before the American Institute of Electrical Engineers, if these figures are realizable the amount of uranium exceeds the estimated coal supply of 3.2 trillion (3.2×10^{12}) tons on a weight basis alone. This becomes even more impressive when it is remembered that each pound of fissionable material will produce 34 billion B. t. u. or 10 million kilowatt-hours of heat which could be converted to 2,860,000 kilowatt-hours of electricity. Each pound of fissionable material, in other words, is equivalent to 1,420 tons of coal.

The possibility of using thorium was discussed in an article in these pages in the October issue.[2] This showed that it may be possible to produce a pound of

[1] The Chicago-Northern Illinois systems are supporting the University of Chicago atomic research program and the Detroit Edison and Consolidated Edison companies have more than an idle interest in the subject.

[2] The Importance of Breeding in Nuclear Power Development. By Andrew W. Kramer, p. 86.

new fissionable material while 1 pound is fissioning. In this process, thorium 232 is converted into uranium 233 which, like U–235, is fissionable.

The "breeding" process has not yet been perfected, but there is reason to believe that it will be. Even without the use of thorium, however, it should be evident that the 5 trillion tons of uranium should last us a long time. As explained in a previous article [3] uranium is present in the earth's crust in the amount of 6 parts per million. In current gold mining practice it is profitable to recover gold from ores that contain as little as 0.3 parts per million. Actually, therefore, a handful of rock or sand or gravel picked up anywhere on earth contains some 20 times as much uranium as is needed in the case of gold ore to make it commercially useful.

ATOMIC ENERGY IN MINING AND REFINING

No doubt considerable power will be required to operate mining and refining equipment in the utilization of low-grade uranium ores but that should prove no deterrent where a fuel with a heat value of some 34 billion B. t. u. per pound is concerned. The atomic power plant indeed would lend itself very well to supplying such mining and refining operations. Needing no water (assuming that the gas-turbine type of plant was used) and almost infinitesimal quantities of fuel, and by its very nature adapted to operation away from congested centers, power plants could be erected anywhere.

So much for the supply of fissionable material. Let us now consider another problem that is frequently advanced as a severe hindrance to the development of practicable atomic power plants, the disposal of fission products. As is well known, in the operation of an atomic reactor, U–235, in the process of fission, is converted into a number of elements of substantially lower atomic weight. These products absorb neutrons and must be removed at intervals before they reach concentrations which would reduce the efficient operation of the reactor. Naturally, these fission products are highly radioactive and dangerous. Some of them have half-lives of several thousand years.

The periodic removal of these radioactive fission products and their disposal constitutes a major problem in the operation of a reactor. Before they can be disposed of they have to be separated from the unused fissionable material, and this also is a difficult operation since it has to be carried on entirely by remote control, behind suitable barriers.

The difficulty of the problem, however, should cause no discouragement. The principles involved are plain and at Hanford, at least, the problem has been solved to a sufficient extent to make the plant workable and without a single casualty in over 4 years of operation. As pointed out in the Smyth report, the maintenance problem was simple—there could be no maintenance. Once the conveying machinery which carried the partially fissioned uranium slugs to the chemical treating plant had been installed and placed in operation, it could not be serviced or repaired. It had to be made absolutely foolproof and reliable. Like the one-horse shay, each part had to be as strong as every other part.

Secondly, the radioactive wastes must all be bottled up in tight containers and stored by being buried in the ground.

Rigid as these requirements are, surely they present no hopeless challenge to power engineers. Modern boilers and turbogenerators operate continuously for a year or more at a time and high-voltage bus structures are quite as deadly as radioactivity if proper precautions are not observed. We live with these things in our daily work and think nothing of them, but we are frightened of radioactivity.

Radioactivity is insidious because none of our senses are able to detect it even if it is present in lethal amounts. But like other problems in this field, it has its solution. There are a number of instruments that will detect it even in minute quantities. With instruments of this kind personnel can instantly detect dangerous conditions or areas and retreat from these areas before harm has been done. The effect of radioactivity is cumulative and a person can be exposed to relatively high levels of intensity for short periods of time. In the Bikini tests, several days after test Baker, I was a member of a group that made a quick inspection of the target vessels on a small ship equipped with Geiger counters. As we approached the old Japanese battle cruiser *Nagato*, the Geiger counters registered 100 roentgen. The roentgen is the unit by which radioactivity is measured and it is generally accepted that the maximum permissible continuous human exposure is 0.1 roentgen. At the moment, therefore, we were being sub-

[3] The Significance of the Nuclear Reactor in Atomic Development. By Andrew W. Kramer. March 1948. P. 90.

jected to perhaps a thousand times as much radiation as a person could safely absorb continually but, of course, we did not linger in the vicinity long. This instance is cited to show that one can be exposed to high radioactive intensities for short periods with no ill effects.

DISPOSAL OF RADIOACTIVE WASTES

As to the disposal of radioactive wastes, frightening as the problem may seem, there is a simple solution—bury it in the ground. Fortunately, the quantities of material involved, even in the operation of a large plant, would be small and no great amount of ground area is needed. There is plenty of ground available to bury the material and a comparatively small number of feet of earth constitutes adequate shielding. While a few of the fission products have long half-lives, most of them probably lose their greatest activity in a matter of weeks or months.

So, while the radioactivity problem is difficult, it is far from being insurmountable and it has been solved to a high degree at the Hanford plant. At Hanford, of course, all operations are carried out by remote control, but that aspect should not concern those of us who are concerned with modern power plants. There are few things in the world today more automatic than a modern steam-electric power station. It is all but devoid of personnel; indeed, a modern high-pressure plant could not operate efficiently or safely under manual control. If the boiler feed water supply to a high-pressure boiler operating at full capacity were interrupted the boiler would run dry in a minute or two in the absence of other controls.

Fortunately the control of a nuclear reactor is simple. It is merely necessary to insert or remove suitable neutron-absorbing rods to maintain the operation of the reactor at any level within the limits of its designed capacity. While the details of the control used at Hanford are not generally known, the fact that the Hanford plant works is ample proof of the fact that the control problem there has been solved.

As a matter of fact, viewing the problem of atomic power development as a whole, despite certain basic difficulties, there is no element in it that is not capable of solution by the application of continued and concerted engineering effort. The greatest obstacle curiously enough has nothing to do with any of the factors here considered. It is the low cost of coal. With ample coal still available at from $5 to $7 a ton, there is little incentive, from a purely commercial viewpoint, to develop atomic power plants.

The commercial viewpoint, however, is not of primary importance at the present time. Too many discussions on atomic power before engineering groups have considered the subject from the standpoint of cost. Costs cannot be ignored, of course, but it is too soon to argue about economics, supplies of fissionable material, and time scales. A recent report of the Atomic Energy Commission points out that it will be some 20 years, even under favorable circumstances, before it would be possible to have any considerable proportion of the world's power supply replaced by nuclear sources. If anything, this is an understatement. It probably will be much longer than 20 years before even a small portion of the world's power can be supplied from nuclear power plants, but that is no reason for us, now, to sit and wait.

If those responsible for the operation of our present power systems ever hope to utilize nuclear energy, it is time to begin now—to engage in extensive experimental work, to begin to accumulate factual data upon which the atomic power plants of the future will be built.

A QUESTION OF SURVIVAL

At a convention of the Controllers Institute of America, Chancelor Robert M. Hutchins, of the University of Chicago, said recently, "Any large industrial concern that hopes to be in business 25 years from now should know what this new weapon, this new physical phenomenon, this new source of energy, this new tool, can do to it and for it." While these words were addressed to a particular group, Dr. Hutchins made it ever so plain that they were addressed to any company, not merely those which can see a direct application of nuclear science to their business right now.

Well, as the Electrical World put it in an editorial, if there be any merit to Hutchins' advice, then the electric-power industry is certainly one which should act upon it. Judging by the volume of 30-year bond issues it has been selling, the electric-power industry expects to be in business 25 years from now and, in view

of what we already know, it is reasonable to assume that no industry will be more affected by or concerned with atomic energy than the power industry.

The problems are many and difficult but the way is clear. The pattern for the nuclear power plant is set; it will be a thermal plant utilizing a nuclear reactor as a source of heat with either a gas or steam turbine as a prime mover. It is as simple as that, but it is high time that we get started.

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32. URANIUM SUPPLIES

Statement of David E. Lilienthal, Chairman, United States Atomic Energy Commission, for press conference in Denver, Colo., December 17, 1948

The potentialities of the atomic age have been sold short several times in recent weeks. Statements have been made and widely publicized, that there is only enough uranium ore to last a relatively brief period, and so the prospects of benefit from atomic power must go glimmering. This is simply not so. It appears clear than atomic energy is on a sound basis for an indefinite period in the future.

An unwarranted impression that a shortage of uranium will drastically limit the possibilities of atomic energy has been caused by estimates that known reserves of uranium would last perhaps only 30 years or not more than 40. Estimates of the total world supply of uranium have run from 30,000 to 500,000 tons, 17 times as much. Estimates of rates of potential consumption of the fissionable material derived from uranium have also varied considerably.

The people of the United States are entitled to know that these estimates of a short-lived atomic enterprise are not correct. If they were true, this would be very serious news. As explicitly as national security permits, the Atomic Energy Commission wishes to state that it finds no basis in fact for these statements about extremely limited uranium ore supplies. If this foreshortening of the atomic age were accurate, the plants and operations of the atomic energy program of the United States would have to close up in a few years.

Instead, the contrary is true about uranium supplies. Estimated known reserves have already increased substantially since usefulness of uranium as a source of fissionable material became firmly established.

Let us look at the facts as they are available generally for making such estimates. Necessarily most of the published data concerning ore deposits and ore reserves is prewar information. Before the war, uranium was used principally as a pigment in the ceramics industry and was essentially a byproduct of radium or vanadium ore. Man has just begun to look for uranium: in every quarter of the earth's surface prospectors' picks are breaking the rocks in this search. The current great prospecting surge may result in the discovery of new uranium deposits that will significantly alter our concept of world supply. Some good prospects are turning up in Canada, to cite only one country. It would be surprising if new discoveries there would not, over the years, equal or better the great Eldorado mine. Only a few new important discoveries would change the world supply picture profoundly.

Nor is it necessary that such new discoveries be made in hitherto unsuspected places. One of the rules of mining is to look for new ore deposits close to known big ones. New discoveries in the Eldorado mine or Shinkolobwe mine in the African Congo would affect the uranium supply position of the world as profoundly as, say one in South America—and would be reflected in production sooner.

Another rule is that good mines die hard. The comparison of measurable ore reserves with rates of consumption at any time means very little in terms of future supply. The prophets of early exhaustion of our petroleum, lead, copper, and other nonreplaceable raw materials have found this out to their chagrin generation after generation.

Recently some figures on petroleum, nonferrous base metals, and iron for the United States have been called to my attention. American Petroleum Institute data have shown an annual increase in the known reserves of petroleum almost every year for a decade or more despite increasing rates of production. Yet, 25 years ago, dire predictions were made that the rate of discovery of new pools was not keeping pace with consumption. Iron may be one of the metals that we have depleted most in this country. Government estimates of iron ore

reserves for 1946, although showing serious decline in the past 20 years because of enormous production, were nevertheless greater than in 1918 and almost as great as in 1908. The iron industry is, however, on the verge of solving the technology of treating vast reserves of low-grade taconite not included in the ore reserve estimates. In addition it will be able to draw on the big, new high-grade discoveries in Labrador, Canada, and Venezuela. The trend of copper reserve estimates has been steadily upward for many years, although the trend of production has also been upward.

Mr. Howard I. Young, at the recent annual banquet in St. Louis of the Industrial Minerals Division of the American Institute of Mining and Metallurgical Engineers, was talking about other metals than uranium, but much of what he had to say is applicable to uranium also. He pointed out that for very good reasons many mining companies spend only enough money in development work to maintain ore reserves of 1 to 5 years. Development work is costly, and frequently it is bad business to make a capital investment in development work that will not yield returns for a long time to come.

One factor that obviously has not been taken into account in these pessimistic predictions about the uranium ore supply is our growing technology and its future application to low-grade sources of uranium. Most metals have gone, or are going through, a cycle where high-grade deposits are at first the only commercial deposits. Then gradually large low-grade deposits yield to man's technical ingenuity and become important producers. This cycle is strikingly demonstrated in the case of copper and lead in this country. At one time 5 percent copper ore was a must. Now important production comes from underground as well as open-cut mining of copper ores containing less than 1 percent copper. It used to require 5 to 7 percent lead to make ore, but for years now lead mines of southeast Missouri have profitably mined ore containing as little as 2 percent lead. In the case of iron, enormous effort is now being put into the problem of utilizing the low-grade taconite of the Mesabi Range which formerly was not considered ore, and there is little doubt but that this effort will be successful. Probably the record for handling low-grade ores to date was the recovery of magnesium from sea water during World War II.

As for uranium, Sweden has already announced that she plans to recover uranium from oil shales, and oil shales and other types of marine sediments which contain small amounts of uranium are under study in this country as in other parts of the world. One important potential low-grade source is that announced recently by the Union of South Africa. The gold ores of the Witwatersrand contain low concentrations of uranium, and byproduct uranium undoubtedly will come from the huge gold-mining industry of that country.

Uranium has been estimated to occur in the crust of the earth probably a thousand times as plentifully as gold or a hundred times as plentifully as silver, and possibly more plentifully than lead or zinc. Figures of this kind, however, have even less meaning than figures for proven ore reserves. It takes considerable concentration of uranium, just as it does of lead or zinc, to make a mineable deposit under anything like present economic conditions. The fact, however, that uranium is not a great rarity lends credence to a geological opinion that it is apt to be present in the right place reasonably often when geological concentrating processes are at work.

The Atomic Energy Commission of the United States is responsible for one of the most extensive and intensive searches for a mineral that has ever been conducted, and on a world-wide basis. We do not expect that there will be an unlimited supply but there is no sound basis for a conclusion that usable uranium ore supplies will not be available for the indefinite future.

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33. AEC ANNOUNCES WESTINGHOUSE CORP. TO CONSTRUCT EXPERIMENTAL REACTOR FOR SHIP PROPULSION

(United States Atomic Energy Commission, Washington 25, D. C. Information or the Press No. 149, December 29, 1948

CHICAGO, ILL.—The Chicago Operations Office of the United States Atomic Energy Commission announced here today that a letter contract has been entered into with the Westinghouse Electric Corp. of Pittsburgh, Pa., for the construction of an experimental nuclear reactor to meet specifications for eventual

use for ship propulsion. Final terms of the contract will be negotiated at a later date.

A. Tammaro, manager of AEC Operations in Chicago, announced that work under the contract will be carried on in cooperation with the Argonne National Laboratory, major center of the Commission's reactor development program. The objective of the developmental project is to meet requirements provided by the Navy Department Bureau of Ships for the propulsion of naval vessels.

The development of such specialized nuclear reactors was among the functions assigned to the Argonne National Laboratory in January 1948 when this laboratory was made the major center of the AEC reactor-development program. Under the terms of this allocation, the responsibility for the design, development, and engineering of the new reactor rests with the Argonne Laboratory. Westinghouse has been delegated responsibility for the detailed engineering, construction, and operation of the reactor, and will undertake such research and development activity as may be assigned to it by the Commission.

The Westinghouse Corp. has had extensive experience in atomic energy work, having made a substantial contribution to the wartime program of the Manhattan Engineer District in the processing of uranium and the manufacture of specialized equipment for use in the U–235 separation plants at Oak Ridge, Tenn. Westinghouse scientists have also taken an active part in other research programs of the AEC.

In announcing the contract, Mr. Tammaro said: "It is the objective of the Commission to produce a nuclear power plant which may be adapted to the propulsion of a naval vessel within the shortest practicable time. Our contract with Westinghouse will bring into the AEC program a company resourceful in engineering and construction know-how, and possessing the widest variety of engineering skills required by reactor development."

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34. PRESS CONFERENCE, ATOMIC ENERGY COMMISSION, DECEMBER 29, 1948

Present: Atomic Energy Commission: Mr. David E. Lilienthal, Mr. Sumner T. Pike, Mr. Carleton Shugg, Mr. Shelby Thompson. Industrial advisory group: Mr. James W. Parker, Mr. Isaac Harter, Sr. Members of the press.

Mr. THOMPSON. Ladies and gentlemen, we will get right down to business and save you time. As you came in the door, there were available to you the report of the industrial advisory group, the covering letter from Mr. Parker and the Commission's letter of acknowledgment to Mr. Parker.

If you don't have copies of those pieces, you may want to get them before we start. We had expected to have here today in addition to Mr. Parker and Mr. Harter, who are present, Mr. Wessenauer and Mr. Wilson, of the advisory group. They unfortunately were unable to come. We had also expected to have Mr. Carroll Wilson, in addition to Mr. Lilienthal, Mr. Pike, and Deputy General Manager Carleton Shugg, but General Manager Wilson of the AEC was taken ill this morning and he is unable to be present, either.

In order that you may get to know these gentlemen a little better, I would like to introduce to you Mr. James W. Parker, president and general manager of the Detroit Edison Co., who is chairman of the industrial advisory group.

Mr. Isaac Harter, Sr., chairman of the board, Babcock & Wilcox Tube Co., Beaver Falls, Pa.

Chairman David E. Lilienthal, of the Atomic Energy Commission.

Commissioner Sumner T. Pike.

Deputy General Manager Carleton Shugg.

Mr. Lilienthal, will you please take over?

Mr. LILIENTHAL. The primary purpose of this conference is to provide an occasion for the press to direct questions to the chairman and members of the industrial advisory group, whose report is released as of tomorrow, and to make the Commission representatives here available to answer questions in connection with this report or any other matter of interest to you about which the Commission is able to throw any light.

The Commission has been fortunate in the past 2 years in being able to call for help from very busy men deeply engrossed in their own affairs. This group of 11 men was appointed in October of 1947, and has put in an enormous amount of time in making a personal inspection of all the installations of the Commission and in a great many discussions with the Commission and its staff.

It would be very inappropriate for us at this time not to express again our appreciation for the kind of cooperation we have had from distinguished men and women in private life in matters affecting the Commission's responsibility.

I would like to have Mr. Parker, the chairman of this group, make such preliminary or introductory statement as he may have in mind in connection with the reports which are in your hands.

Mr. PARKER. Mr. Lilienthal and ladies and gentlemen, I think it is important in the first place that all hands realize the nature of this report. It is, of course, that of a consultative group. By no manner of means is it to be considered a criticism of what the Commission has been doing, or of the Commission's methods of operation, but, rather, it is intended as helpful advice and comment on accomplishments in the past, and with regard to the courses of the Commission in the future. In other words, the relationship of our group to the Commission is that of a consultant to a client.

Now, it may strike you as containing a great deal that is rather obvious. The measures that are recommended, the comments that are made, are all rather simple matters. If the report has significance, it is because in spite of the fact these are simple matters that we are discussing, they come representing the consensus of the thinking of a competent group of men, and I am not referring to myself but to the others who served with me on this advisory group. It was a good group, representative of quite a broad cross section of industry.

I am particularly glad that the report could deal with matters that could be immediately published. I hope that in that respect it will have something of a reassuring result in the minds of industrialists.

There is no second report. There is no undercover report, auxiliary, or supplementary report to this at all. This is the report, and it represents practically all of the thinking of this group.

I think you must appreciate that these men serving on this advisory group are not themselves scientists—certainly not nuclear scientists. Their comments are rather from the standpoint of the man who is concerned with the methods for getting things done, and that is why a great deal of the report deals with this matter of better information being gotten into the hands of industry in general. I think you would all realize from reading Mr. Lilienthal's original instructions to this group, and from his other public statements, that he looks forward to the time when the operations of the Commission will at least approach the free competitive enterprise type of work that American industry is able to do. For instance, in the munitions program, when industry was given tasks that were at first very unfamiliar, but which were ultimately solved in industry's own way, industry came back and said, "Here is a better way to do it."

That, as you know, has been evidenced over and over again, throughout the whole war experience. Now it is that kind of thing that this group had to consider. We were given free access to as much of the secret information of the Commission as was necessary. We saw their installations. There was nothing that we did not see that we needed to see, and yet, it was not the techniques of the Commission's operations that we were most concerned with: we were concerned, rather, with the effect on industry, and the possibility of getting a better participation by industry in a competitive sense, where they could come in and find, we will say, a profit motive for engaging in this work.

Mr. Lilienthal, I don't know if there is anything more I need say in a general way. A reading over of the report will indicate the general feeling of this advisory group which has, after all, had a rather intimate look at the operations of the Commission with a general conclusion that the Commission is doing a good job under extraordinarily difficult circumstances.

I think I will say just a word about one recommendation which you will find here in the report and that is the recommendation that there be established a continuing advisory group, a standing industrial advisory committee, not to deal with the techniques of atomic fission, or of the chemistry of these processes, but, rather, to advise continually along the lines of this report.

Otherwise the report cannot be as effective nor, possibly, as perfectly interpreted by the Commission, as it will be if there is a consultant who will continue to interpret, who will watch the developments as the Commission makes them, and either change the recommendations or assist the Commission in changing its courses as these developments occur.

In other words, I believe strongly, as do the other members of this committee, that there should be available to the Commission a standing industrial advisory group which will continue what we have attempted here, and that is a better

understanding on the part of industry of the opportunities of becoming active in this work.

Mr. THOMPSON. I presume we are open for questions at this time, Mr. Lilienthal?

Question. Mr. Parker, I call your attention to the fact that we have here both your report and the response to it from the Commission, and I would like to ask you quite specifically whether you regard the response as a satisfactory response to your recommendations, particularly as regards the paragraph in your report on page 6 dealing with the difficulty in getting a broad industrial attack on the problems of atomic energy. The response to that is on page 2 of the Commission's response.

Mr. PARKER. Give me time to run through that paragraph.

Question. I mean specifically are you satisfied with the plans that they are pushing ahead with?

Mr. PARKER. I am satisfied that the moves that they are now making are decidedly in the right direction. Now just a word as to whether we are satisfied. That is where your standing advisory group would be of use; they could say whether they think the Commission is making progress. Our group obviously cannot always say that we think they are moving in the right direction.

Question. Mr. Parker, more specifically, along the same line, may I ask it this way: Do you consider that contracts with Westinghouse and du Pont, which are the things mentioned on page 2, do represent progress toward the type of thing you are talking about at the bottom of page 5 and on page 6; that is, competitive industry getting into this field?

Mr. PARKER. Yes, sir; it is a beginning.

Question. In what way is it a beginning?

Mr. PARKER. I shouldn't say a beginning; a change for the better. There are already large industrial concerns engaged in this work, notably the General Electric Co. Neither du Pont nor Westinghouse, until this announcement, was actively in it. This is a good move.

Question. That, then, would be a step, but it is still on a hired-hand basis?

Mr. PARKER. How it works would be for this continuing group, if there is such a group, to say.

Question. I would like to ask Mr. Lilienthal if he would expand the thought behind the sentence on page 2 in the same paragraph, beginning, "You will of course recognize," where you speak about information most important to potential competitors.

Mr. LILIENTHAL. This is simply a way of saying that while it is true that the operations at Oak Ridge and Hanford are industrial operations and that they do involve industrial technology which undoubtedly has value to American industry and therefore to the whole country beyond the field of fissionable materials, they also happen to be the key technological developments of importance to national rivals of this country in the development of atomic weapons, and this is the heart of the problem of secrecy in the field of industrial technology.

Question. Aren't your competitors other nations?

Mr. LILIENTHAL. That is right.

Question. Mr. Lilienthal, it has long been said that our technological know-how is our real atomic secret; it has been repeated time and again. Over the persons who now have security clearance, you have some control, do you not, through contractors or otherwise?

Mr. LILIENTHAL. Yes, we do.

Question. How would it be possible to clear for restricted data several hundred technologists who would operate in your plants and about your plants for a while and be able to go out? You say that it is not insuperable; how are you going about that?

Mr. LILIENTHAL. Well, it is so difficult that, although the advantages are quite great, the Commission will certainly have to go at it with caution. This is not to say that these several hundred—or perhaps more than that—industrial executives and technicians wouldn't, as a class, be trustworthy, but the fact that they are not regularly engaged in this work would make the problem of security control one of a different order.

Question. Apparently you wouldn't have the same control over them as you would over your own people or over your contractors.

Mr. LILIENTHAL. Well, we don't really have control over contractors or our own people in that if they are indiscreet or careless or worse our control happens after the event, after the eggs have been cracked. But our own employees and employees of contractors do present a different kind of security problem

in that they are continuously engaged in this work and their sensitivity to security is something we can help and watch. We probably can't do that with consultants in the sense that is recommended here, and we believe well recommended. This is a constructive idea. Its development in practice is going to increase our problems of dissemination and nondissemination of certain kinds of information by manyfold.

Question. Does your reply imply that you are now going to work out some formula for the clearance of several hundred of these technologists?

Mr. LILIENTHAL. Yes; we are trying to develop a plan that meets the recommendation of the industrial advisory group whereby a considerable number of specially equipped industrial executives and technicians in the various fields referred to here can be investigated, cleared, and given access to the restricted data for the purposes cited in this report. This involves two questions. One we have just referred to, and the other is that there must be a kind of screening process. It would be very difficult to get work done if we were not sure that the men from industry had an assignment that made them take this extremely seriously and not as a casual matter. The point is that you can't ask the many hard-pressed and harassed men and women working on this job to take on the additional responsibility of advising with a great many consultants unless you are sure that those consultants are ready to spend several months continuously at this work. Neither of these questions is insuperable. The advisory group is just as aware of them as we are. I am very glad they made the recommendation. We do think something in this direction will work out, but there is no use kidding ourselves or kidding the public. Whenever you add to the number of individuals not presently engaged in your work as employees or contractors, you do by that much add to the problem of security and add to the responsibilities of the Commission. Everyone recognizes that. There are no easy problems in this job as far as I have been able to discover after 2 years of looking for them carefully, and this ranks high among the difficulties.

Question. Sir, would it be your idea that these new people would kind of go to school in a tight-knit group, or would they just be free?

Mr. LILIENTHAL. I think the advisory group's recommendation implies that they should confine themselves to an inspection and analysis of operations and research work under way and consultation with men doing this work; casual visits are not contemplated, as I understand it.

Question. Mr. Lilienthal, is it within the Commission's present power to carry out such recommendations as have been made, or would amendments to the Atomic Energy Act be required?

Mr. LILIENTHAL. It is within the Commission's authority in that the Commission is authorized to make restricted data available, properly limited and properly developed, where it will promote the common defense and security. It would make the country stronger technically if the great mine of technical advance that is represented in this undertaking could be more widely disseminated among industry. The balance against that is that there is involved certain additional security risk. The whole question is whether that risk is greater than the values to be received. In principle, although the gain probably would outstrip the risk, practical operation of such a scheme would take some doing.

Question. That would apply to all the recommendations? It is within the Commission's power to carry them out? You wouldn't need special amendments to the law?

Mr. LILIENTHAL. As far as I know, there is nothing here requiring amendments.

Question. Mr. Lilienthal, along the lines of getting outsiders—that is, noncontractor industrial people—more informed, whatever happened under the industry advisory provisions in the General Electric Schenectady contract to implement those provisions?

Mr. LILIENTHAL. There are other non-General Electric industrial people under the General Electric contract, and that contract and other contracts containing similar provisions will help. They will not go as far, however, as Mr. Parker and his group feel is necessary, and as many of us feel is highly desirable.

Question. Mr. Parker, do you find that the atomic energy program has been held back in any way by any of the criticisms mentioned in your report?

Mr. PARKER. If the Commission's organization had been perfected from the first moment, if you can imagine such a thing, obviously they would have made better progress than they have made under the circumstances in which they have operated. That they have gone as fast and as far as you could expect the organization to go, under the circumstances, I think can be fairly said; and I believe that is our thinking.

Question. Mr. Parker, I would like to ask you this. I believe that the step forward that the McMahon Act brought about was to transfer atomic energy from military control to a civilian commission, with the presumption that if we moved along it could be expanded and made open to industry in general. Now, after 2 years of operation under this act, do you believe that that was a step in the best interest of the Nation?

Mr. PARKER. I am not competent to speak on the question of whether the military branch of the Government or a civilian agency should, as a matter of philosophy or Government policy, handle atomic energy but the change to a civilian organization undoubtedly brought about changes in the set-up. That was inevitable. The civilian organization set up for itself a very much wider, more comprehensive program than that of the military.

Question. Mr. Parker, as a result of your study, have you any ideas on possible new uses for atomic energy in industrial fields, or can you give us any thoughts on what industries you think might become interested in this program?

Mr. PARKER. We have, as you realize, refrained from talking about the technical side because we were not atomic technicians or physicists, but we couldn't go through the experience of seeing the plants and talking as we have with members of the staff without thinking of various new uses which we would like to see explored. But we are hardly competent to advise the Commission. We can best talk about methods.

Question. As an industrialist, as a man who has been through these plants and who has seen some of the potentialities, what would you like to see? What are the things that industry would be interested in exploring?

Mr. PARKER. Divorcing myself from my own industry, I might say one's first expectation is that we would be interested in seeing power development. For my part, I am not any more interested, personally, in that than I am in seeing this energy used in any one of several other ways.

To be quite honest, our greater interest is to see enterprises like du Pont, Westinghouse, and so forth, engage in the thing along the lines that interest them, as General Electric is undoubtedly engaged, because, in the long run, it is the profit motive that makes those industries click and makes those teams perform.

Talking of my own particular industry, I think that the public has possibly placed a wrong interpretation on a good many things that have been said, and said without the slightest intention of misleading them. The public has rather misled itself into thinking that the development of atomic power as a substitute for power generated from some other fuel source is not only fairly immediate, but of utmost importance.

As a power-generation man, I am not nearly so interested in that phase of it as you might expect.

Question. Mr. Parker, on page 9 of your report you recommend an engineering analysis of the power question. I don't find, at least in reading it, any response to this specific recommendation: "Another and perhaps wiser approach would be to accept the offer of the American Society of Mechanical Engineers to make such an analysis for the Commission."

Mr. PARKER. Acceptance of the offer of one of the engineering societies is referred to in your reply, is it not, Mr. Lilienthal? I will try to answer specifically about what we had in mind.

I have attended meetings of the American Society of Mechanical Engineers at which there has been attempted a sensible discussion of the problems that may arise for mechanical engineers in the course of this atomic energy development. They are not very productive discussions, because the people sitting in the audience, in the first place, have not been cleared. They don't know what is behind the screen, and, not knowing what is behind, they are very loath to discuss even the implications; and, by the same token, members of the Commission staff who sit on the platform in these conferences are unable to say very much. So here they are all thinking about the same general problem, but as if they had no language in which to convey that thinking.

The engineers, on the one hand, won't venture to make proposals, and the Atomic Energy Commission men, on the other hand, are unable to tell them specifically what some of the problems are. And so, if a group of responsible men, certified to the Commission as being responsible, trustworthy, and, of course, to be checked up on in the usual way for clearance, could understand as much of the techniques of this operation as, of instance, the members of this advisory group understand them, those discussions would be much more productive.

Now, in the matter of atomic power as a substitute for power from conventional sources, in my opinion there can be a great deal of work done by engineers who understand the value of power as developed and made available under various circumstances. To illustrate what I mean, if this power is a byproduct of some operation for military purposes out in the State of Washington, it is obviously low-grade power. It hasn't the economic significance that it would have if you were able to operate such a plant within transmission distance of an industrial center.

It isn't particularly important to substitute atomic energy for the cheapest fuel that comes into any community; that is, the fuel that the central stations are burning. If it could be in some other form it would be much more interesting. Electricity, for example, has peculiar value because it is a high grade of energy and invaluable because of the ease of control of its application. I am just trying to illustrate that there is an economic difference in the forms and places in which such energy can be made available.

Now, that is the sort of study on which engineers who are conversant with the power field and the economics of it could, with advantage, put some time. However, they have to have some knowledge of the circumstances under which the power would be forthcoming.

As I say, it might be a byproduct; it might be a primary product; it might be tied down geographically; or by some stretch of the imagination, it might be portable fuel that could be available most anywhere. Work has to be done sometime to determine what the economic value of this energy is as it turns up in various forms and circumstances.

There is no reason why the engineering profession shouldn't be working on that problem, and why the Commission, as far as I can see, shouldn't simply hand the problem over to them.

Question. Mr. Parker, does what you are saying come down to this, then: Instead of the Commission deciding it has a problem of some type and asking some industry or firm to solve it, the Commission should throw out the general scope of all problems involved in atomic energy, other than military, and let the industry sort of play around and see what they can come up with?

Mr. PARKER. Yes; I think that is a pretty good outline of what I was attempting to say. You realize that isn't secret information.

Question. Mr. Lilienthal, you mention in your letter, sir, that one of the companies was working on a ship-propulsion problem—a reactor, I believe it is—for a ship. Is that the only thoroughly civilian use of atomic energy on which any private industrial concern is working?

Mr. LILIENTHAL. No; the whole reactor program for the development of atomic power falls within that category, and that includes General Electric's reactor which is now under design and soon to be under construction near Schenectady, and the comparable reactor for atomic-power production at the Argonne Laboratory near Chicago.

Question. Mr. Lilienthal, did I understand you to say that you and the Commission feel that all of these recommendations are highly desirable and you would like to see them in effect, but, as to whether or not they could be carried out in the details presented is a matter of weighing technological advancement against security; is that correct?

Mr. LILIENTHAL. Security, and, to some extent, practicality of operation. And also to what extent some of the recommendations—at this point, when we are under such urgent pressure for shoring up and strengthening the enterprise—can be fitted into the energies available and the time available.

That is like saying that we are against sin and for good, though, because it leaves you that same balance, so you come down to deciding in particular cases whether this part of the proposal on balance seems more advantageous than risky. This is true of so many of these things; for example, the report on engineering evaluation of heat energy, to be useful, in the way in which the advisory group contemplates, ought to be a published document. If it is only available to those people who have been cleared, instead of having a closed group of Commission employees and contractors, you would still have the group enlarged only by a few hundred people who still can't really cross fertilize the rest of industry and other engineers. And so that assumes a public document, at least that is what we are always driving toward, and yet, a public document of that kind, before it is made public, must have a good deal of specific information taken out of it, or this law would have no meaning. We would be repealing the law by its administration and virtually saying that there is no such thing as restriction.

So we have to attack each specific case and see if, on the facts, it would justify such dissemination.

It is also true that this advisory group of practical men is quick to recognize some of these things are desirable at one time but not feasible at another, because there just isn't enough time and energy to do some of these things at any particular time. In many instances, these reports, to be really useful, have to be drafted in part by the directors of laboratories. They must be done by men upon whom a great pyramid of things already is resting. Otherwise they get delegated to people who are simply writing stuff. These advisory men all recognize that. It is a matter of timing.

The thing about the report that pleases me so much is that it will elevate to a high level of priority and importance the problem of dissemination of industrial knowledge.

Question. You mentioned, sir, that you are under terrific urgent pressure for shoring up the enterprise. What do you mean by that, sir?

Mr. LILIENTHAL. That is what we have been doing the last 2 years.

Question. Are you speaking of security, or do you mean production of a military potential?

Mr. LILIENTHAL. No; I am just speaking to this point of why don't we do everything at once. No one has suggested doing everything at once, but one of the reasons why one has to kind of pick and choose among desirable things is that 2 years ago we had an operation threatened with discontinuity of production, and it was in considerable jeopardy for technical reasons. Two years ago we had an operation whose capacity for producing fissionable materials out of which weapons were made was too low in view of the security requirements of the country. We had to concentrate on those things and get them under way. Those things are now under way and it will soon be time to put more effort on things of less urgency in that sense. That is what we have been up to these last few years, to keep the thing from stopping and increasing production capacity. In those instances, you lay out a program and move as fast as you can, and then later, you have time to effectuate such fine recommendations as this report embodies.

Mr. PARKER. If I may just add to that, Mr. Lilienthal, I think we have been quite aware, even in just the year that we have been having contacts with the Commission, of a speeding up of the process of improving the organization and methods of accomplishment.

Question. Mr. Lilienthal, what you have just said in kind of vague language sounds as though the United States at this time has what the military considers to be sufficient atomic weapons for emergencies; is that right?

Mr. LILIENTHAL. Well, that would be a military question. I didn't want to be too vague. I said this program was threatened with discontinuity. That means that it might have stopped unless something was done about it.

Question. You say that now you have time to turn——

Mr. LILIENTHAL. Now it won't stop.

Question. The urge is less pressing today?

Mr. LILIENTHAL. Because a very large-scale new enterprise has been begun—the largest peacetime designing and construction job in the history of this country—and is rolling. It isn't rolling as well as we want, but it is definitely rolling. First things come first, and those were the things we went at first. They are under pretty good steam.

Question. Mr. Lilienthal, is that peacetime construction at Hanford, Wash.?

Mr. LILIENTHAL. I meant construction in peacetime. Yes, Hanford and other places, but principally Hanford.

Question. Was the whole program of production of fissionable materials threatened with discontinuance, or just at this one place?

Mr. LILIENTHAL. At Hanford.

Question. Mr. Parker, would you be willing to elaborate a little more on the specific thing you think industry might be able to do besides possible power development? I am sort of unclear as to the specific direction you think private enterprise ought to be going, let's say, in the next 5 or 6 years.

Mr. PARKER. In the first place, I think a careful reading of the report will indicate we think industry will itself, in its own processes, benefit by some of the techniques, some of the materials, that are being made available through radioactive isotopes. These are new metallurgical techniques, new chemical treatments, new plastics, new instrumentations. These are, you might say, byproducts of the Commission's operations. Those things can and will be useful to industry and are already becoming so.

That is one phase. There is where industry will derive benefit for its own operations. We were also concerned in seeing that industry is also engaged in some of these as yet unsolved problems on which the Commission is working. There they will be working for the Commission and making a large-scale contribution, as some of these large contractors did in the past and are still doing—General Electric, Monsanto, and some of the others.

I don't know whether I have quite answered your question. If they are in this work and contributing effectively as teams, and not just loaning some competent men; if they are in there using all their wits and resources, as, for instance, General Electric and these others that have been mentioned undoubtedly will, they can make a contribution which the Commission would never have available to itself if they just borrowed these same men.

Question. Could you name some other firms, or, for example, special types of enterprise?

Mr. PARKER. We have mentioned, of course, Westinghouse. I don't know whether I have said this before, but I think it was too bad those two great organizations (du Pont and Westinghouse) were not in it throughout, and working as they are now, now they are back in it. The other firms are more numerous than we have time to count over—firms like Monsanto, Carbide & Carbon—my memory is too short to tell you, but there are a lot of them.

Question. Is there any interest in stimulating new business people, people who are starting out new enterprises in this country?

Mr. PARKER. The Commission would like to see new industries stimulated. They are welcome. In their reply letter they referred to the fact that a number of companies are developing new counters. They welcome that. They like to see these people in there developing in the traditional way that competitive business does develop. They will benefit by it; the Commission will benefit.

Question. Mr. Lilienthal, can you give us any reaction to the suggestion at the bottom of page 13 about setting up a corporation owned by other corporations? I am particularly interested in the parallel with what I understand to be the operation of some of these educational operations.

Mr. LILIENTHAL. That is a very interesting suggestion, and we are studying it. We haven't any further comment on it.

Mr. THOMPSON. I want to make an announcement, before any of you find it necessary to leave. All the information growing out of this conference not pertaining to the Industrial Advisory Group's report is for immediate release. We would like to have you hold the information pertinent to the report for Thursday a. m.'s.

Question. Mr. Lilienthal, I think a lot of common people in this country are vitally concerned about one problem. It is the only problem we are concerned about and come back to it all the time. That is, Do we have reason to assume that we are the only nation who is the sole possessor of the atomic weapon?

Mr. LILIENTHAL. Well, I agree with the first part of your statement that this is a question everybody is concerned about. But no one in the Commission can respond to that question because it involves foreign intelligence, and the present policy of the country—and it is a wise one—is to deal with our dissemination of foreign intelligence with great caution, for reasons which I am sure are obvious. I am sorry, that is the best I can do on that. Or to put it another way, it would seem to be against the interests of this country to disclose from official sources to potential international rivals what we know, or say we know, about their progress.

Question. Might I straighten out one thing? I am not dead sure yet whether there was any response to this recommendation on the report of the American Society of Mechanical Engineers or not. Is that an accepted recommendation, or is it under advisement?

Mr. LILIENTHAL. It is being studied. We have had this report only a week.

Question. Mr. Lilienthal, I would like to get that discontinuity of fissionable materials straightened out a little bit better. At what time did it look as though the program was threatened with discontinuity?

Mr. LILIENTHAL. The first time we had a look at it.

Question. What date was that?

Mr. LILIENTHAL. About 2 years ago. The transfer was on the 31st of December, and this was shortly before that time.

Question. So it meant building another plant; is that right?

Mr. LILIENTHAL. Well, it meant a number of things: Taking measures to see that interruption didn't occur in existing plants, to the extent that was possible; and building additional plants.

Question. Could you spell out the interruption at all; was it mechanical or personnel?

Mr. LILIENTHAL. Well, you couldn't produce fissionable materials with the plants you had. No, not personnel reasons, but for technical or mechanical reasons. This is not surprising. As a good many of you know, these plants were built straight from the laboratory with no pilot plant, no intermediate plant. It is a miracle that they operated at all and that they operated that long. This is not a criticism by any manner of means of du Pont; it is just a fact.

Question. Was it just a matter of lack of facilities rather than any handling of the project itself?

Mr. LILIENTHAL. Just the physical facilities.

Question. Didn't that have something to do with the power potential on the west coast?

Mr. LILIENTHAL. No.

The plant itself was an experimental plant built at full scale to start with. It was the first time any such thing as this had ever been done, and that it developed difficulties and deterioration is not surprising. And if the world had been so fixed that there was no urgency, the security factor would have been a matter of no great concern.

Question. Was it due in any way to military management of the plant?

Mr. LILIENTHAL. No.

Question. That has been completely overcome at this point?

Mr. LILIENTHAL. No. What we have under way are additional plants, new plants, and remedial measures. The remedial measures have proven very satisfactory, indeed.

Question. If you had the plant, Mr. Lilienthal, even though the facilities were not of the best, could you not have produced fissionable materials at the same rate that they were produced in that plant during the war?

Mr. LILIENTHAL. Not if the plant wouldn't operate. It either operates or doesn't operate.

Question. I mean the operations were just shutting down due to defective equipment?

Mr. LILIENTHAL. If the plant couldn't operate because of the troubles that had developed and had to be shut down, then you just wouldn't produce fissionable materials.

Question. Why didn't the same thing happen at Oak Ridge, sir? I don't understand why it happened at one and not at the other.

Mr. LILIENTHAL. Well, they are quite different kinds of plants, and it just didn't. I am not being coy. It was quite a different kind of operation.

Question. Is it fair to say that Hanford broke down? [Laughter.]

Mr. LILIENTHAL. No.

Question. What happened at Hanford?

Mr. LILIENTHAL. Well, I obviously can't reply with precision except to say it seems to me from the point of view of public information it is enough to say that a new plant designed from a laboratory stage to a factory-size stage developed troubles, some of which were anticipated. These were troubles that were not due to design because no one could have anticipated what would happen to materials in a reactor. That is one of the great problems we have. Many of these materials have never been subjected to this high radioactivity.

Question. Did continuity cease at any time?

Mr. LILIENTHAL. No.

Question. I don't see how you can say it didn't do a good job.

Mr. LILIENTHAL. It did. It didn't break down. It threatened to stop.

Question. Mechanical troubles were developing which would have caused discontinuity if not improved?

Mr. LILIENTHAL. That is right.

Question. During this time you were having trouble at Hanford, was it possible to produce fissionable material at Oak Ridge?

Mr. LILIENTHAL. Yes; that is quite a different kind of operation.

Question. You used the terms "deterioration" and "remedial." Do you mean that this new plant will not deteriorate as rapidly or that you have licked that problem of deterioration?

Mr. LILIENTHAL. Well, one can't say, because we are dealing here with new materials and new reactions, any more than one could say when this plant was designed how it would stand up. When you have had experience with a turbine or a metal in an internal combustion engine, then you can predict about its

future, but when you don't have experience with or knowledge of the materials, it is different.

Question. What is the duration of your experience with the new plant as compared with the one which deteriorated?

Mr. LILIENTHAL. Well, it hasn't been put into operation yet.

Question. Were the troubles rectified in the older plant?

Mr. LILIENTHAL. Yes; we are continuing to operate at a high level.

Question. Can you say when the new one will be in operation?

Mr. LILIENTHAL. No.

Question. What was the cost of the old one, do you recall?

Mr. LILIENTHAL. Do you know, Mr. Thompson?

Mr. THOMPSON. No.

Mr. PIKE. $350 million.

Mr. LILIENTHAL. Those were days when a dollar had some value.

Question. What is the relation of this new Schenectady plant to the rest of the program?

Mr. LILIENTHAL. General Electric at Schenectady is building for us a research and development laboratory and a reactor. This is an atomic machine that is expected to produce heat from which heat energy can be developed for production of electricity. The purpose is production of usable energy.

Question. Mr. Lilienthal, will the operation of the new plant at Hanford entail building another dam on the Columbia?

Mr. LILIENTHAL. No.

Question. Mr. Lilienthal, this is a kind of basic question. Do Oak Ridge and Hanford do the same basic thing; do they take the same basic material and end up with the same result?

Mr. LILIENTHAL. No.

Question. They do different things entirely?

Mr. LILIENTHAL. The Oak Ridge plant produces uranium 235; and the Hanford plant produces plutonium.

Question. Will the new plant at Hanford produce at a greater rate than the old one; can you say that?

Mr. LILIENTHAL. We are now considering just how much may be said in our report to Congress about production capacity, but certainly it is intended to increase the production of plutonium as well as to insure continuity.

Question. About how much will the new plants cost altogether?

Mr. LILIENTHAL. Well, the scale of investment is about that of the wartime investment. But with all the chemical processing plants, it will run more than that, probably on the order of a half billion dollars.

Question. Plutonium is produced only at Hanford, isn't it, Mr. Lilienthal?

Mr. LILIENTHAL. Yes.

Question. Mr. Lilienthal, I am under the impression that a large portion of the Commission's funds are going to the military. With that in mind, would you say that the more significant developments as far as transferring atomic power to industry are concerned will come through military projects such as the submarine project which was recently begun?

Mr. LILIENTHAL. Well, there is this comment. It would seem likely that the first application of useful power from atomic energy would be where the economic factors are the least important. A warship or a submarine powered by an atomic reactor would have advantages to the country which would probably outweigh the relatively high cost as compared to, say, oil-burning power plants. The same thing is true about the location of an atomic power plant in an area where conventional fuels are very high cost or inaccessible. It is the same proposition. It is quite likely that the first application will therefore be in an area where economic factors, as in the case of propulsion of submarines, are less important than strategic or other considerations.

Question. Would you say, also, that one of the limiting factors now is a shortage of fissionable materials for experimental work?

Mr. LILIENTHAL. No, not for experimental work.

Question. For production work?

Mr. LILIENTHAL. No. This is a relatively scarce material, and there is never enough of scarce or valuable things. But there is no shortage in that sense. Any sound experimental project requiring fissionable materials has thus far been able to be taken care of.

Question. Is what you have said about Hanford usable right away, or must that be held in connection with the report?

Mr. THOMPSON. I would say that is usable right away.

Question. Mr. Lilienthal, has the Commission yet made the allocation of fissionable materials for 1949?

Mr. LILIENTHAL. No.

Question. Will that be coming soon or will there be any argument about it?

Mr. LILIENTHAL. It will be coming soon; whether there will be an argument I don't know. There hasn't been any argument yet.

Question. How about your scientists? We have heard they have been disturbed during the last year? Do you have enough of them, or are they still interested in the program?

Mr. LILIENTHAL. You don't count scientists by numbers. The men of great ability are rare and we never have enough, but I think the situation in that respect is considerably improved.

Question. Morale, that is?

Mr. LILIENTHAL. Yes.

Question. Or know-how?

Mr. LILIENTHAL. Morale, I think, is considerably improved. It is a tenuous thing.

Question. Would Mr. Parker amplify that situation about the conflict between the physicists and the engineers and who was running the show?

Mr. PARKER. I will if I can. I may be quite in error in my size-up of the scientist who has been doing a pure research job. I think he has to work without very much guidance. He has to follow the path wherever it may lead. In other words, if you try to direct his thinking and his investigation, you are liable to jog his elbow as you would if you tried to to direct a composer of a piece of music and tell him how to compose it. There is your pure scientist. He is really not impatient with control; he is unable to work with control.

At the other end of the picture there is the engineer, who is not a scientist but who has some knowledge of scientific results and methods and whose sole job is that of applying scientific knowledge and devising methods, taking into account all variables, in other words not working in a theoretical field. It is the difference between theoretical and practical. Sometimes he has to work by cut and try and by empirical methods, anything to get it done. I am quite convinced that a great many of the accomplishments during wartime must have been done with insufficient knowledge. This very effect that Mr. Lilienthal has been mentioning, the effect of operating those plants at Hanford, illustrates it. They had to go on without knowing the answer; you see what I mean? They had to take what knowledge was available at the moment and get busy and apply it. There is bound to be a conflict between those two types of persons and those two types of thinking.

Question. Well, is the statement in your report based on that theoretical situation you have set out, or did you find some actual situation?

Mr. PARKER. It really is more than a theory; it is a very practical thing. I don't believe that the Hanford plant would have been built and operated if it hadn't been in the hands of a team of men who knew how to take what knowledge was available and put it together in a plant; and they must have had to make some decisions that shocked the scientists because they couldn't wait for the answer. They just had to try it.

Question. Did you find that the scientists were trying to tell them what to do or what not to do; is that what you mean?

Mr. PARKER. If you start a project and tell the scientist to pace it and make all the decisions, the other type of man isn't going to get much done while he is waiting for the scientist to investigate the whole field. I am elaborating a little beyond the report now, but these are my personal observations.

Question. I note in your report that you seem to feel a great deal of material should be declassified and made available to industry. Can you tell us what you feel about the security safeguard around the material that should not be declassified? What has your group found as far as security of our atomic program is concerned?

Mr. PARKER. You have asked two questions. First, Do I think it should be kept secret? There are some portions of it that undoubtedly must be. Certainly none of us think that the Commission would be justified or Congress would be justified in just turning the whole thing loose. Now, you want to know whether everything that could be declassified has been; is that the point?

Question. No; are we properly safeguarding what should not be declassified?

Mr. PARKER. Yes; I think so. It is all screened and processed and worked over with extreme care.

Question. Can you give us some idea of your conception of the type of material that should be declassified?

Mr. PARKER. We tried to make that somewhat clear; matters of organization, matters of contract methods, some of what might be called byproduct processes, materials, instrumentation, that kind of thing that will be extremely useful to industry and knowledge of which, without its context wouldn't be of much use to competitors in the field of atomic fission.

Question. Thank you.

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35. UNITED STATES AEC NAMES DR. LAWRENCE R. HAFSTAD DIRECTOR OF REACTOR DEVELOPMENT DIVISION

(United States Atomic Energy Commission, Washington 25, D. C., Information for the Press No. 152, January 16, 1949)

The United States Atomic Energy Commission today announced the appointment of Dr. Lawrence R. Hafstad, who has been executive secretary of the Joint Research and Development Board of the National Military Establishment, as Director of the Reactor Development Division of the Commission.

Dr. Hafstad is the first Director of this new Division which was created in August 1948 to carry out the program of designing and developing nuclear reactors for the practical application of atomic energy for power, for propulsion of ships and aircraft, for production of isotopes, and for research on reactors themselves. About $120,000,000 is in the President's budget for the coming fiscal year for the reactor development program.

It is principally through the development of reactors that the Atomic Energy Commission expects in coming years to develop a means for utilizing the energy released by nuclear fission.

Dr. Hafstad, with two colleagues, Drs. Richard Roberts and Merle Tuve, demonstrated uranium fission for the first time in the United States in 1939 in Washington following reports from abroad that German scientists had split atomic nuclei.

Dr. Hafstad has been on leave of absence from Johns Hopkins University where he holds the position of director of research of the Applied Physics Laboratory at Silver Spring, Md. It was in this laboratory that he helped perform much of the work leading to development of the proximity fuze and also took part in research and development work on guided missiles.

Dr. Hafstad became executive secretary of the Research and Development Board July 1, 1948. His responsibility there has been to work with the policy committee which considers strategic applications of scientific developments and to coordinate the work of groups in various developmental fields.

His scientific and administrative experience especially fit him for his vitally important duties with the Atomic Energy Commission. These include responsibility to General Manager Carroll L. Wilson for the activities of the Chicago Operations Office, which gives administrative support to the Argonne National Laboratory, the center of reactor development, and the program at Knolls Atomic Power Laboratory at Schenectady, N. Y.

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36. THE ATOM AND THE BUSINESSMAN

(From Fortune, January 1946. Reprinted by permission.)

> * * * it is hereby declared to be the policy of the people of the United States that, subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace.

With this resounding declaration of policy, the Atomic Energy Act of 1946 began. Sponsored by Senator McMahon of Connecticut, and signed on August 1 of that year by President Truman, it yanked the entire apparatus of atomic energy out of the hands of the Manhattan District, Corps of Engineers, U. S.

Army, Major General Leslie R. Groves, commanding, and placed it under the control of the civilian Atomic Energy Commission, which the act created. It was a bold stroke for the Seventy-ninth Congress, and the shades of the Founding Fathers must have nodded in approval. But in demilitarizing atomic control, Congress handed to the new Commission an absolute monopoly—and thus a power, responsibility, and entanglement of a kind and size hitherto unknown in the civilian administration of national affairs.

It is now two and a half years later. In mid-January President Truman will place before the Congress his proposed budget for the fiscal year 1950 (beginning July 1, 1949) and in it the requested appropriation for the AEC will be most conspicuous, for it is fair to guess that it will reach one billion dollars. If that is conjectural, this is specific: for fiscal 1949, now only half gone by, the Commission will spend well over $600 million, and in fiscal 1948 it *did* spend $463 million.

What is it all for? It is for Oak Ridge, where fissionable U–235 is separated from non-fissionable U–238, where radioactive isotopes are produced for research and, in a slight way, for industry. It is for Hanford, Washington, where the element plutonium is created. It is for Los Alamos, New Mexico, where the bomb is made. It is for the Argonne National Laboratory, the Brookhaven National Laboratory, the Oak Ridge National Laboratory; for the great Knolls Atomic Power Laboratory that is rising in Schenectady, New York, and for such comparatively lesser establishments as the Mound Laboratory in Miamisburg, Ohio, and the Ames Laboratory in Iowa. It is for the Radiation Laboratory at the University of California. It is for so many things that the crowded double-spread map on pages 58 and 59 (*q. v.*) can show only a few and barely suggest their interconnections.

WHOSE ATOM IS IT?

Any story of the atom is a story of vast and conflicting anomalies, at any plane of thought. For example, although the McMahon Act demilitarized the atom and spoke of "increasing the standard of living," "private enterprise," and "world peace," and although the scrupulous AEC Commissioners earnestly believe in all these things, the biggest fraction of money spent and activity engendered by the AEC today is for military purposes. Pretense upon this point is useless. It is not merely that we are stockpiling bombs. There is the NEPA project—Nuclear Energy for the Propulsion of Aircraft—a Buck Rogers concept that the Fairchild Engine and Aircraft Corp. is studiously pursuing at Oak Ridge. There is the project for submarine propulsion by atomic reaction on which Westinghouse Electric is beginning to work with the U. S. Navy under the AEC's all-encompassing eye. But beyond all this there is the vast activity, involving constant new plant construction, new power, new factory operations to produce fissionable materials in greater and still greater quantities. The expansion of the Hanford Works *since* V-E and V-J days, 1945, will when completed bring it to three times its maximum war investment. When an international accord on the atom became impossible, the U. S. went to work to see that it would never be left behind in the atom's military aspects, and it is not.

Consider another anomaly: despite its 1949 expenditures of over $600 million, the AEC is not a large governmental body; the expenses of the Commission for its own self-sustainment this year will be only $26 million, or about 4 per cent of the whole. Its five Commissioners, led by Chairman David E. Lilienthal, are the policy-making bosses of some twenty-one administrative executives headed by General Manager Carroll Wilson, who in turn boss some 5,000 assistants and clerical workers in Washington and in the field. (This may be compared to the Department of the Interior, which has a budget of $408 million yet employs 52,000 people.) Even so:

The AEC has a larger investment in real estate, plant, and equipment than General Motors Corp.

Runs more buses than the city of Philadelphia.

At Hanford alone has an inventory with the same number of items as the Montgomery Ward catalogue.

Owns or leases more land than all Rhode Island.

Could not use the Empire State Building as a warehouse: much too small.

How does the AEC go about the daily business of conducting its colossal affairs? It does it almost entirely through the channels of Business and Industry—so that among governmental agencies it is not only unique in itself but does things in a unique way. Over 90 per cent of its 1949 expenditures will

go to "contractor operations." For example, Carbide & Carbon Chemicals Corp. will get $60 million for its operations as a prime contractor at Oak Ridge; Monsanto Chemical will get $7 million for basic research in Mound Laboratory in Ohio. Far and away the biggest of the AEC's business relationships is with its major prime contractor, the General Electric Co., which will receive from the Commission this year something like $208 million for its vast plutonium work at Hanford, Washington, and more diverse affairs at Schenectady, New York. Out of this, G. E. will immediately subcontract a sum of perhaps $116 million, mostly to big construction companies, and itself will expend the balance of $92 million.

To its seven biggest industrial prime contractors, the AEC will pay out $313 million, so that over 50 per cent of the Commission's whole 1949 spending will go directly and immediately to business and industry. But three other prime contractors make up the AEC's "big ten" for 1949. The University of Chicago will get $35 million for running the Argonne National Laboratory as a *business;* the University of California will get $37 million for running the Los Alamos Scientific Laboratory and its own Radiation Laboratory as a *business;* and Associated Universities, Inc.,[1] will get $27 million for running the Brookhaven National Laboratory at Patchogue, Long Island, New York, as a *business.*

From this perspective it might be thought that businessmen were flocking to the Commission's banners; beating trails to Washington either to be cut in on the pie of a big new AEC budget or, more nobly and smartly, to find out how they might alter their commercial affairs to be in at the start of the Great New Future. But here one confronts what seems the largest anomaly of all: few are doing any such thing.

This passivity Mr. Lilienthal regards as one of his greatest problems. Far from trying to keep the atom all to himself, as some suspect, the Chairman of the AEC is busy trying to push as many of its affairs as possible out into the great stream of private enterprise where, says the McMahon Act, competition should seize it by one of its many valences and do—something—with it. The McMahon Act seems to offer great opportunities to private industry, but private industry looks at the act's administrators, the AEC, and coldly asks, "For example, *what?*" Even the great prime contractors, although they preserve a most decorous cordiality toward the AEC, occasionally mutter into their bourbon that it is patriotism, mostly, that keeps them at their tasks: either the tasks are profitless, they say, or they could make a great deal more money with the same management and manpower doing something else in realms of their own choosing.

And so the flat fact is this: no major company in any industry in the U. S. has so far made a private capital investment of one penny in the atom.[2] The relationship of the businessman to the atom is that of a hired hand, nothing more. Is it that the peacetime atom has no future, after all we have heard? Is there no long-term atomic risk for risk capital to take?

The trouble with the atom is, to the businessman, that its future is dazzlingly bright, but hopelessly vague. There are only two tangible things about it at which he can even hope to grasp: isotopes and power. Beyond that, there is abstract promise, nothing more.

The first of these is tenuous and ramified as gossamer. Radioisotopes are presently much more attractive to science than to industry. Direct industrial applications, although potentially numerous, have been retarded by a legitimate concern for radiation hazards that no one not a radiophysicist knows enough about. Nevertheless, some industrial uses are in sight. Gamma rays from powerful radiocobalt might supply better radiographs of heavy steel shapes than a million-volt X-ray machine. The weak rays of radiocarbon are being used by Goodyear Tire & Rubber Co. in an instrument that gauges the thickness of plastic sheets to one hundred-thousandth of an inch. Other radioisotopes, incorporated in chemical compounds, can signal the presence of poisonous industrial fumes the instant a leak occurs. But, in general, radioisotopes are produced *by* research *for* research. They *might* win the war against cancer next week, and they also *might* in some fashion, in no way at present suspected, solve other enormous problems in the domains of medicine, biology, agriculture, or industry. So

[1] Associated Universities, Inc., is a coalition, for atomic purposes, of Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Tech, Princeton, Pennsylvania, Rochester, and Yale.

[2] Such capital investment as there has been comes from small, new companies like Tracerlab Inc. of Boston, and Nuclear Instrument & Chemical Corp. of Chicago. There are at most a handful of these.

industry must watch the world of isotopes like a hawk, and in general it is doing this, but it is tiring work, and there is no hint of money in it. To the AEC, radioisotopes are at present its only source of atomic income—this year some $250,000; not much return on the investment.

There remains power from nuclear fission. This is a much more contentious subject, upon which miscellaneous "professors" shoot their mouths off several times a week. But in the AEC's fourth semi-annual report issued last July its General Advisory Committee urged that no one consider power from nuclear reactors as an important commercial possibility until at least twenty years from now. There will be power piles long before then, but they will be experimental only.

INTERLUDE ON POWER

How do you get from the fissioning atom in a chain-reacting pile to electric power? There are literally thousands of ways. "My goodness," says Walter Zinn, Director of the Argonne National Laboratory, "I could give you so many drawings of reactors you'd have to haul them away in a truck." Basically the problem is the old one of converting heat to mechanical energy to electricity. In a pile the temperatures potentially available run to millions of degrees. Yet at Hanford the piles are water-cooled, i. e., they operate below 212° Fahrenheit. Warm water will not light any lamps. The search is for a pile coolant (liquid bismuth, for instance) that can be taken off at high temperatures, the higher the better. Passed through heat exchangers, this could convert water to high-pressure steam, and the steam could spin a conventional turbine hooked to an electric generator. The coolant, on the other hand, might be a gas like helium that could be expanded directly through a gas turbine, again hooked to a generator.

After the mechanico-electrical system is selected there are scores of alternatives left in the pile itself. The usual fuel in present piles is pure uranium metal, the usual moderator (the material that slows the neutrons down to atom-splitting speed) is highly purified graphite. But the fuel could be fortified with U–235 or plutonium (made on other piles) to any degree of enrichment. The moderator might be heavy water, or even beryllium.

It is no great trick to make a pile work. It is not even a breath-taking feat to draw off a little power. (The British achieved the first power pile—100 kilowatts—in August, 1947.) What the AEC is after is something vastly more important—a "breeder" pile. Here is the great key to the future of atomic power. At present the only source of energy is U–235, which makes up only one pound in every 140 pounds of natural uranium. (The other 139 pounds is powerless non-fissionable U–238.) At present, to turn one atom of U–238 into useful plutonium requires the expenditure of at least one atom of U–235—a profitless procedure. Enter "breeding." If one atom of U–235 could be tricked into producing *more* than one atom of plutonium, the atomic empyrean would wax considerably brighter. All the presently useless U–238 could then be converted to plutonium and power. By breeding, thorium—Th–232—could also be converted into fissionable U–233. Theoretically breeding is possible. It should be possible to wrap uranium and thorium around a pile like a blanket. Excess neutrons husbanded from the chain reaction would enter the blanket and make plutonium and U–233. At intervals the blanket would be removed, fissile atoms extracted. "Nevertheless," says the AEC, "the engineering difficulties associated with breeding are enormous. * * *"

WHICH BUSINESSMEN ARE THEY?

So once again the businessman is left up in the air. If David Lilienthal and his Commissioners cannot bring him down, that is only for the same sort of reason that Thomas Newcomen, around 1710, could not define much use for his steam engine beyond unwatering English coal mines. The complexities that surround the atom and the businessmen are, further, the insistence on secrecy in the name of security, the uranium and fissile-materials monopoly vested in the Commission, and the patent restrictions of the McMahon Act, which in effect assign to the Commission the control of what comes out of atomic research. All this makes some U. S. businessmen just plain mad.

Among U. S. business concerns many atom-attitude classifications can be devised. For example, there are companies that neither have nor want AEC contracts; companies that want them and don't have them; companies that don't want them but do have them; companies (rare) that have them and want them.

both. But on the level of industries it is perhaps more helpful to make five groups, like this:

(1) Industries that have nothing to do with the case—except, perhaps, for research programs (e. g., the huge tobacco industry)
(2) Industries that may sometime fit, but don't yet (e. g., the automotive industry)
(3) Industries in the atomic world but not of it (e. g., the industrial-plant-construction industry and big equipment suppliers)
(4) Industries on the periphery, now partially drawn in (e. g., the oil industry and its plant designers)
(5) Industries in which pertinent research and production have long been indissoluble (e. g., the great chemical and electrical industries)

And now, having made our divisions, let us mostly ignore all but the last—for although Mr. Lilienthal and his Commission must in one way or another consider all five, the great motive power for progress springs mostly from the high technology industries. The Atomic Energy Commission today, like the Manhattan District before it, deals largely with the biggest of big industry. This policy leaves it politically vulnerable to charges of favoritism, of fostering and compounding monopoly, but it solves another problem that could plague the Commission even worse. The equations are:

DEALING WITH BIG BUSINESS=SMALL AEC

DEALING WITH SMALLER BUSINESS=HUGE AEC

and the Commission has chosen the former. With this limitation, there are only a few companies in Group Five that can even be considered as a means of directly fostering the Commission's fundamental work—and quite a number of them don't want to play. Here is a list:

E. I. du Pont de Nemours.—Du Pont, with its own construction company, built the Hanford Works during the war, operated it for the production of plutonium, and did a capital job. After the end of World War II it got out of the fissionable-materials business like a shot, and turned everything over to General Electric, which General Groves brought into Hanford as its successor, before the AEC took over. Presumably, du Pont got out because its policy makers had developed an industrial psychosis over the "merchants of death" accusations they encountered after World War I; also, perhaps, because du Pont and the U. S. Department of Justice are in such an entanglement over antitrust contentions. But there are already hints that du Pont is on its way back into the atomic-energy program, presumably because it cannot technically afford to keep out.

Allied Chemical & Dye.—This huge enterprise is a wild cat that walks by its wild lone, and doesn't even like to fraternize with its own chemical-company brethren. It never had a contract in the atomic program during the war.

Tennessee Eastman.—This subsidiary of the Eastman Kodak Co. was a prime war contractor for the electromagnetic separation plant at Oak Ridge during the war. It was famous for the degree to which it stood on the absolute letter of the law of its contract, and when it retired on May 1, 1947, both sides heaved a sigh of relief.

Dow Chemical.—This company was too busy with other war-production affairs to serve the atomic program in wartime, but the AEC is just now bringing it into a research program on "important new chemical separation problems."

American Cyanamid.—Major producer of fertilizers, dyes, plastics, and pharmaceuticals. Cyanamid was offered only two small atomic-research contracts by the Manhattan District during the war. The work it did has never been declassified. Cyanamid has so far shown no interest in doing anything more on the atom.

Monsanto Chemical.—Was a prime contractor at Clinton National Laboratory (now Oak Ridge National Laboratory) from mid-1945 to March 1, 1948. Then it retired, "so that it could transfer its atomic work closer to home." Today Monsanto runs the Mound Laboratory (chemical research) for AEC at Miamisburg, near Dayton, Ohio. Monsanto's vigorous Executive Vice President Charlie Thomas is on record with the belief that the AEC Commissioners pay too much attention to "the academicians" and not enough to industry's engineers.

Kellex Corp.—Designed the gaseous-diffusion plant at Oak Ridge during the war. Now is responsible to General Electric for process design, and is similarly involved with Dow Chemical.

Westinghouse Electric.—Just now entering the program directly, although it has had for six months a subcontract from the University of Chicago for Argonne National Laboratory.

Carbide & Carbon Chemicals Corp.—This subsidiary of Union Carbide is now the prime contractor that runs the gaseous diffusion (K–25) and electromagnetic separation (Y–12) plants at Oak Ridge, as well as the Oak Ridge National Laboratory for the AEC. See below.

General Electric Co.—The prime contractor for all operations at Hanford, Washington, where plutonium is created, and also the largest single contractor for atomic research. See below.

Consider now briefly the two case histories of the two biggest prime industrial contractors to the AEC.

Carbide & Carbon at Oak Ridge

Only one U–235 extraction process is in operation here today: the famous $500-million gaseous-diffusion process—K–25—designed by Kellex (Fortune) November 1948), built by J. A. Jones Construction Co., operated from the start by Carbide & Carbon Chemicals Corp. Given only an outside chance of working, K–25 went into operation smoothly and soon greatly exceeded the performance calculations of its designers, both in U–235 purity and in production rate.

Heart of K–25 is a gigantic U–shaped building (see page 55), each wing about 400 feet wide and half a mile long. Inside, uranium hexafluoride, a gas, is pumped a distance of some eleven miles through thousands of porous barriers, each perforated by billions of holes smaller than two-millionths of an inch. Gas molecules containing U–235 move slightly faster than molecules containing heavier U–238 and thus find their way through the barriers slightly more easily. Acres of barriers were mass-produced by Houdaille-Hershey Corp. (supplier of accessories to the auto industry), thousands of novel pumps, some whirling at velocities above the speed of sound, were built by Allis-Chalmers, over 100,000 control instruments were provided by Taylor Instrument Companies to make the prodigious operation go.

In addition to the operation of K–25, Carbide has two other important jobs at Oak Ridge. It produces, for use in fundamental research, stable isotopes (from Y–12) and radioisotopes from the pile of Oak Ridge National Laboratory.

Today Carbide and the AEC get along well enough. The AEC takes two positions, and sticks by them. The first is that its own "directed operations" offices (see map, pages 58 and 59) are semi-autonomous; the second, that when it hires a contractor it pushes all the responsibility for that contract onto him, and aims not to interfere in his operations. The AEC reserves to itself the basic functions of establishing the pace, scope, and emphasis of the program. Since a perfect working out of this managerial split is not possible, a certain supple diplomacy is necessary between John C. Franklin, head of the Oak Ridge AEC office, and Clark Center, resident boss for Carbide—but the point is that the diplomacy works (accompanied by a certain amount of tough kidding between AEC administrators and Carbide's staff). If there have been disputes between these two, none have ever yet had to be carried outside the area for settlement.

Although the AEC inherited some "$1 a year" or "no fee" contracts from the Manhattan District, Carbide's present contracts are on an acknowledged profit-making basis; this year it is receiving a fee of about $1,900,000 on contracts involving $60 million. This 3.2 per cent return is something that Carbide knows very well it can exceed in the rough and tumble of its own daily free enterprise in the outside world. A certain amount of grousing and bitching goes on among the Carbide staff at Oak Ridge, on the theme of "working for the government"—but it has the quality of the grousing and bitching in a good regiment of a good army. The AEC people, whether at Washington or at Oak Ridge, are likely to begin sentences with the expression, "Of course these Carbide people are tough, but. . ." The sentence usually ends in some sort of compliment for the job being done. Yet though Carbide is deeply involved in the program for atomic energy, it has no plans to invest one penny of its own capital in any private effort in this field. Pressed for an answer as to whether Oak Ridge could contribute anything to Carbide beyond its fee, Engineering Vice President H. E. Thompson thought for a minute and said: "This is a frontier in a new technology. Carbide has pioneered before—in gases, alloys, chemical processes. It is glad of the opportunity to pioneer again. No question the future is uncertain, but we're willing to string along."

G. E. at Hanford

The case of General Electric is unique. Indeed, the dimensions and variety of its relationships with the AEC are so large as to raise, in one instance, almost all of the unanswered questions of how to do business in the atomic age.

G. E.'s biggest job is to operate the first nuclear chemical factory in the world. The immense job of designing, building, and operating the original three piles and three chemical-separation plants of Hanford was accomplished by E. I. du Pont de Nemours in two and a half years flat, between January, 1943, and June, 1945. Du Pont labored in secrecy and retired in silence; the incredible task it performed will never be fully comprehended until du Pont chooses to talk. While Hanford called for the same quality of engineering audacity as Oak Ridge, the problems at every step were vastly complicated by the presence of nuclear radiation of an intensity never before experienced. (In the course of creating the plutonium needed for one atomic bomb, the radiation equivalent of somewhat more than one atomic bomb is generated.)

On September 1, 1946, du Pont stepped out, its contract having specified that it be relieved at the earliest opportunity, and General Electric took over. As we have seen, Hanford's postwar expansion has been tremendous. It is no secret that G. E. began by having plenty of trouble. It attempted to run this biggest of all atomic projects without adequate staff—no resident labor man, no resident lawyer despite hundreds of subcontracts, no cost analysis—more than a year after it had taken over. Some harsh words were exchanged, and as a result eminent G. E. Vice President Roy C. Muir was brought out of retirement in April, 1948, to take charge of the lagging affairs—and G. E. had to borrow some thirty management men from du Pont to help get itself straightened out. "Frankly," says Harry Winne, Vice President in charge of G. E.'s Engineering Policy, "we didn't forsee the size and scope of the project; we didn't realize the top caliber of the personnel we needed there."

Things are humming at a much higher pitch under Mr. Muir, who by now feels he can retire for the second time. This month a younger man, Vice President George Prout, formerly in charge of G. E.'s Air Conditioning Department, becomes general manager of the new Nucleonics Department, and thereby takes charge of Hanford operations. The Hanford personnel has grown until it now comprises 10 per cent of G. E.'s technical staff and 6 per cent of its labor force—G. E.'s importance in the whole atomic program, as well as the degree of its own involvement with it, is as well borne out by these simple statistics as by others more complex.

But now turn to G. E.'s operational contract; even a cursory examination spells out many of the unresolved questions of policy in this strange world of atomic business. The contract is an inheritance from the days of General Groves and du Pont. This four-year contract, which last year called for an expenditure of $141 million, provides for $1 of "profit" for its duration. In it, however, there is an item for "overhead" of $2,400,000 each year. This is a subject of discord, for AEC accountants believe that some—"or all"—of this sum is profit, whereas G. E. officials are vehement that if it were not for "this loophole" (G. E.'s word) they would be losing money on the whole business. The contract says: "It is the intention of the parties that any excess be returned to the government." This means that in September, 1950, after the four-year contract is run, a sum of $9,600,000 will have to be adjudicated. At that time AEC, which is the boss, may allow or disallow part or all. This will be "renegotiation" of a sort, but not the most satisfactory sort. The final result will scarcely be as clear-cut as the agreed $1,900,000 fee that Carbide & Carbon takes from Oak Ridge this year, for example.

G. E. AT KNOLLS

General Electric illustrates another problem point between the atom and the businessman. When General Groves asked G. E. to take over Hanford, he also discussed the matter of putting government money into what is now known as the Knolls Laboratories, in Schenectady, G. E.'s home town. No suggestion was ever made to G. E. that taking over Hanford was the price of getting government money for Knolls, yet the net result today is that the AEC's contract with G. E. is a single contract, covering Hanford and Knolls both. And what is Knolls?

Knolls was once a big 360-acre private estate five miles northeast of Schenectady, which G. E. acquired in 1946, with the intention of building there a new laboratory for its own general purposes, to supplant its old laboratories, now hopelessly intermixed with other buildings, from which so many scientific developments have come in the past quarter century and more. This new laboratory of GE's own, known as K–1, is now half finished and partly occupied; its probable cost to G. E. will be some $20 million. G. E. split the acreage in half, and on this other half the AEC is building, with public money, for GE's use in research on the atomic program, a government laboratory (K–2), which will be

staffed and run by G. E. scientists and engineers. This building is now in the concrete and structural-steel stage, and to the AEC it stands today as a $25-million commitment. It is for atomic research exclusively; either for the purposes of Hanford and plutonium, or for power from atomic reactors. Seventeen miles away, at West Milton, New York, an experimental power pile is soon to begin going up—also with AEC money, and to be operated by G. E. Present estimates of its costs are $20 million. A large amount of experimental work has had to precede or parallel the building of K–2 and the power pile, and the AEC investment or commitment envisioned in association with G. E.-Knolls is now in the vicinity of $45 million—scaled down from $60 million as AEC budget time approached. And once again, as with Carbide, G. E. is not risking a penny of its own capital funds directly on the atom.[2]

Should it? Its Board of Directors obviously thinks not. G. E. says, with sincerity, that it is "more careful of the government's money than of our own." But there is one fact of enormous bearing on the problem of present-day pioneering costs, and G. E. is a focus of it: when government foots the bill the final tab may well be from three to five times greater than if private industry bore the cost. This is not because of carelessness in *spending*, but because of the psychology of *asking* for what is to be spent: a rich uncle always has a relaxing effect on even the most sturdy nephew.

NO PROFIT TO WHOM?

What benefits does G. E. derive from its AEC contract that redound to its advantage as a private company? It would seem to derive a good deal, disregarding the overhead "loophole." As operator of the Knolls K–2 and the West Milton pile, G. E. is in the first line to benefit from future atomic-power possibilities. It is obtaining immediate experience with a host of auxiliaries: isotopes, new instruments, new plant conceptions, new gadgets of every description. It is able to train and develop men at government expense.

No criticism of G. E. is intended here. The intent, however, is to raise a question: how much money can a private company take from government and still retain its privacy? Is it wise from G. E.'s own viewpoint to accept so deep an involvement in the atomic program? Per contra, is the AEC pouring too much money into its association with G. E. for the country's own good? Might not Westinghouse, only now in contract negotiations with the AEC, have been cut in on some of these activities? Westinghouse is not so large and ramified a company as G. E., and does not have so great a richness of scientific facilities as G. E. has built up over the years: that, indeed, is a reason the AEC gives for its primary consideration of G. E. It is written into the G. E. contract for Knolls that the AEC may install up to 15 per cent of the research staff from outside companies, and five Westinghouse engineers are currently working at General Electric under this provision. To broaden this idea still further, the AEC plans to appoint an advisory board to weigh and consider the claims of other "outside" interests in the laboratories so that they will not be monopolized. Of course, since the AEC holds title to the K–2 laboratory and the West Milton power pile and buildings it can always order General Electric to move over when a contract runs out, but this is pretty strong medicine, unlikely to be administered except under some extraordinary circumstance.

When asked if it ever regrets taking on the infinite complexities of the atom, General Electric replies, in the words of Vice President Winne, "Yes, but not for any length of time." He adds, "We took it on, and we are prepared to see it through."

Now General Electric, with its vast stake in power and its pioneer position in pure and applied research, has every reason for "seeing it through." The words "patriotism" and "sense of duty" constantly occur in its officials' conversations on the atom, and the words are obviously sincere. But the word "profit" never occurs. Why not? The AEC Commissioners, led by Mr. Lilienthal, would *like* the word profit to occur in G. E.'s language and in G. E.'s thoughts. But there is an unsolved problem here, and that is, how to make industry less timid about—of all things—profits. Profits from "working for the government" are certainly not in the same category as private profits; thus they give the businessman nightmares of being grilled by a congressional committee. Certainly a statement of principle from government is needed here to

[2] Many companies have made contributions to existing research programs for a variety of nuclear studies.

emphasize that profit from government work on the atom is neither "profiteering" nor "munitioneering." On this point the AEC is now evolving a philosophy about profits that needs publicizing: it is that future industrial contracts should include them. They must, it is true, be subject to negotiation and renegotiation. Since in "working for the government" on the atom the ordinary profit-and-loss system is suspended and there are no open markets to buy or reject a product, it can only be the AEC itself that decides how much profit this or that company is to make—on its record as the AEC sees it. Industry may not like that, but if industry is wise it will not on that account cling to the soft and meaningless sentimentalism of working for a hundred pennies a year, for in this sentimentalism there are terrible dangers to the private-enterprise system.

OTHER WAYS TO DO IT?

Some months ago a member of the AEC's Industrial Advisory Group[4] asked a pertinent question: was there anything, either within the McMahon Act or in the policy of the AEC, that would prohibit a group of private companies from pooling resources to build and operate their own atomic reactor free of "interference" from the government? The Commission's answer was no, there wasn't.

There are modifications to the no, important or unimportant according to who views them. The AEC would have to be in charge of maintaining security. It would have to supervise health and safety provisions for the area affected. Since the AEC is a monopoly in its field, the private operators would have to lease their uranium from the Commission and allow the Commission absolute power to decide which patent claims must be assigned to it. How onerous are these provisions? No honest private individual wants to have possession of a gram of fissile material unless an army of federal cops is there to protect him. As to patents, the General Electric Co. itself discounts their value: in this field it is experience, not a patent claim, that is the controlling factor.

Yet even though the Commission has no primary objection to a private pile, there is faint likelihood that such a pile will come into being. The burden of proof is all on him who says it will. A power pile, plus appurtenances, is a $50-million investment—plus the wisdom and experience to operate it. Why should private industry currently do more in this area than be the government's hired hand? In work with the atom, anything can change in a flash, but as of January, 1949, it would seem that the following is an axiom:

> The absence of spontaneous private-investment interest in the atom is due to the absence of any present visible sign of dollar return therefrom.

Two good friends of Mr. Lilienthal, both of them deeply concerned with atomic problems, worldwide and industrial, and both of them businessmen of the highest order, have strong opinions on the relationship between the atom and industry:

Bernard Baruch: "I am not in favor of any private company, anywhere in the world, owning an atomic-energy plant."

Chester I. Barnard (now President of the Rockefeller Foundation, and an original member, when he was President of the New Jersey Bell Telephone Co., of the five-man board of consultants that produced the 1946 Acheson-Lilienthal report on international control of atomic energy): "I am not an advocate of government ownership, but I don't think you can do anything else in this field. The government must finance such work."

These opinions would seem to limit industry to the passive role it now plays. But here is where the final anomaly appears: although industry *won't* invest in the atom, and the Messrs. Baruch and Barnard say it can't, industry does not like its passivity. Apparently, in this field, it simply does not know how to be truly active. Like the Lord, the McMahon Act giveth, and taketh away. And it has the businessman quite naturally confused, because the act never says how the strengthening of free competition in private enterprise is to be squared with its numerous injunctions against what used to be normal business processes in a pre-Atomic Age.

What the businessman seems to enter, once he is fully admitted to the atomic circle, is an economy of limited profit and no risk. What he seems to lose is what he has enjoyed in the past as he sees it: his prime entrepreneurial function. He is the servant, not the boss.

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[4] A report from this Group, criticizing present AEC policies and methods, is expected in mid-January. Its Chairman is James W. Parker, President of Detroit Edison; its membership consists principally of executives in the oil and power industries. Despite an excellent personnel, the Group seems to have been having a hard time formulating its advice.

But as a servant, he has his rights. One of the most important of these is his wages. If the businessman takes the position that he can accept no more than a dollar a year profit for working on the atom, then certainly he is himself helping the Atomic Age to become also the profitless age—the very thing he decries. If, on the other hand, industry were to demand more profit from the atom—frank, open, fair, unashamed profit—and ask for less government-furnished capital goods, he might thereby begin to regain some of his old entrepreneurial spirit. There *were* days in which businessmen invested their own moneys in great laboratories with no knowledge at all of what might come out of them—in fact, it was General Electric more than any other company that ushered in that exciting era.

A remark of extraordinary realism recently came from a businessman remotely but importantly connected with the atomic-energy program, who said: "Commercial interests and national interests are simply not the same thing. Nothing short of actual warfare gives them even the semblance of similarity."

If that is true, then what Mr. Lilienthal is hunting for is what William James years ago could name but not find: a Moral Equivalent for War; something that will really bind diverse men's conflicting interests together while there is still even a limited peace on earth. Mr. Lilienthal is hard and conscientiously at it but he has to have help for it is a transmutation more difficult to cause than anything that has so far taken place in the Atomic Reactors that stretch, A. D. 1949, from Hanford to Patchogue.

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37. SOME ASPECTS OF NATIONAL SECURITY

Address of Rear Adm. R. A. Ofstie, USN, before the Reserve Officers Association at Memphis (February 17) and Knoxville, Tenn. (February 18, 1949)

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There are naturally wide differences of opinion as to what constitutes an adequate defense establishment, what form and organization it should take, and what the composition of its units. Some of these opinions are based on the experience of war, some are based on reasonable expectation of new developments, some are frankly based on fantasy. It is undoubtedly an American trait to be receptive to any easy and quick solution if based on the slimmest plausibility. The fact is, however, that there is no cheap solution. The promises of new methods and weapons, so common immediately after the late war, have not borne fruit. I cite the guided missile as perhaps the best example of a world-shaking development, presumed just around the corner, which has failed dismally to appear in the time promised and which is still far in the unpredictable future as an important weapon of war.

Somewhat the same situation applies to atomic power for aircraft, on which there has been some rather fanciful speculation. An evaluation of this subject has recently been completed, under the sponsorship of the Atomic Energy Commission, by a group of prominent scientists. It is hoped that their report will soon be made available in unclassified form for public information.

In the light of current knowledge the prospect of a useful atomic-powered military aircraft is a very long way in the future indeed. Certainly it is so far away that it can have no possible effect on current planning. There is no present expectation that through the expedient of atomic power we will have aircraft of unlimited range and highest performance.

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38. NORTH AMERICAN AVIATION CONTRACT

(United States Atomic Energy Commission, Chicago Operations Office, Chicago, Ill., Information for the Press, March 2, 1949)

Awarding of a contract to North American Aviation, Inc., for research and development in the general field of nuclear reactor technology with particular emphasis on the investigation of materials and components suitable for the practical application of atomic power, was announced today by A. Tammaro, manager of Chicago Operations Office.

The special research section of the company's aerophysics laboratory is carrying on a program which includes both long-range fundamental research as well as immediately applicable developments.

The contract is an outgrowth of some of the research and development studies initiated several years ago by the United States Air Force and carried on by North American Aviation's aerophysics laboratory. Since this work was pertinent to the needs of the Atomic Energy Commission as part of its development of atomic power and other applications of nuclear reactors, the AEC contracted with North American Aviation to continue these studies. The contract is in accord with the Commission's policy of fully utilizing the research and development capacities of industry in the interest of national welfare.

The future development of the nuclear reactor for the generation of atomic energy, the production of fissionable material, and research, depends very largely upon the development of structural materials and components suitable for operation under the special conditions found in high-power, atomic-energy units. For this reason, the program of North American Aviation in this field is expected to make a significant contribution to the development of atomic power and its applications.

The activities of North American Aviation in this field are part of the program of the Reactor Development Division of the AEC, and are coordinated with the AEC National Laboratories and other contractors engaged in the development of atomic power.

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39. ATOMIC ENERGY IN RELATION TO GEOLOGY

Remarks of Commissioner Sumner T. Pike, United States Atomic Energy Commission, at the annual meeting of the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Exploration Geophysicists, St. Louis, Mo., March 16, 1949

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The third area in which anybody interested in petroleum should obviously be interested is that of power from atomic energy. There is power in nuclear fission. No one who has seen photographs of the explosion of atomic bombs or of the aftermath can have any doubt on this point. As a matter of fact, for a considerable period after the first explosion there was too much imagination turned on not only by the comic-strip artists but by a good many competent scientists who made quick translations from the atomic bomb to costless power to light and heat our homes, propel our automobiles, turn the wheels of our industries, and even solve the water problems of southern California. These predictions have turned out to be a little optimistic.

On the other hand, the energy from atomic fission can be controlled in the chain reacting pile and it is more than a possibility that useful power can be extracted from it. I hope you may be interested at this point in a rather sober factual survey of the hurdles to be topped before this prospect can be turned into a reality.

In the first place, unless somebody comes up with a completely new idea of which there is yet no hint, nuclear energy must first be converted to heat. This part is easy. However, we are dealing with a very, very expensive fuel. Therefore we must attempt to get as great efficiency as possible out of this heat cycle. This means probably much higher temperatures than have previously been considered practicable in power plant design—temperatures at which structural steel begins to be unsuitable. This is merely an extension of a familiar design problem.

However, in our structural problem, we have something quite new to us. To maintain a chain reaction requires that at least one of the neutrons which is emitted at each split of a uranium 235 atom shall strike and split another U–235 atom or otherwise the reaction will die out. Now all elements to a greater or lesser degree absorb or cancel neutrons.

Therefore one of the basic musts in the design of a reactor is that any material used, either for structural purposes or for heat exchanging, must absorb a minimum number of neutrons. In other words, we must cut the neutron loss down to the lowest possible point if we are to get any efficiency in operation.

This requirement taken together with high temperatures probably means that we shall have to go to some previously little-used metals or possibly to refractory ceramics for structural purposes.

Besides the internal structural problem, we also find it necessary, for the protection of the people in the vicinity, to surround the whole active mass by extremely heavy shielding which will absorb or deflect the intense radioactivity which could otherwise be completely lethal. This problem has been quite simple for the stationary reactors so far built. It has only been necessary to put 5 or 10 or more feet of concrete around the whole works.

For any probable large stationary power plant in the future the problem does not seem particularly difficult, but when, as is most likely, we get to placing propulsion plants aboard ships, we then face space and weight limitations which mean we must sharpen our wits, intensify our research, and get better answers than we have so far. When space and weight limitations get as acute as they would necessarily be for application to the automobile, there is just no solution on the basis of present knowledge.

It is fair to say here, however, that this is a subject about which almost nothing is known and vigorous research over the next few years may cause us to modify our views.

But, to get back to consideration of the problems related to reactors for power when we come to the heat exchangers which take the heat out of the pile toward the generator, the same familiar factors hit us again as steam as conventionally used seems quite unsuitable. High-temperature steam means high pressures which require heavy tubing in the pile and a great loss of efficiency through neutron absorption. The obvious resort is to such inert gases as helium or to liquid metals or alloys which won't require high-pressure tubing. In either of these cases the heat exchanger must not be a heavy absorber of neutrons, nor can it be allowed to carry out into the power plant radioactivity from within the pile.

Within an active pile running at high power we are probably going to be dealing with the radioactive equal of tons of radium and it may turn out to be impossible to use a heat exchanger which will not carry some of this radioactivity outside the pile. In this case it will be necessary to use a second set of heat exchangers which might at this point give us the sort of steam with which to operate a conventional turbine.

Up to date we have been dealing with problems which, while difficult, look susceptible of solution and it requires no great stretch of the truth to say that they are well in hand. However, we now come to a set of questions which may not keep us from having some sort of power from nuclear energy but which could if no solution is found prevent us from ever having power at a cost which would be bearable in any but the most highly specialized applications.

The uranium or plutonium must be of exceptional purity when originally placed in the reactor—I use pile and reactor as interchangeable names—but when the reaction starts the fissionable materials start splitting up into fragments which themselves represent some 40 or 45 elements, and immediately introduce the impurities which we have so carefully removed. Apparently we have no possible method of controlling what these adulterating elements shall be. Some of them will have highly deleterious effects on the very reaction of which they are the result. Therefore from time to time it will be necessary to remove the nuclear fuel and repurify it before it can be used further in the furnace.

These impurities, lethally radioactive as they are, must not only be removed from the fuel but must be stored or treated in such a way that they will not cause damage to people or things. The optimist can look forward to the time when radioactive wastes will form the basis for other industries just as some of the byproducts of early organic chemistry became much more important than the ones on which the industry was originally based. But at the moment we can only call these wastes nuclear garbage and arrange for their harmless disposal.

My present attitude is that a satisfactory solution of these chemical problems which I have mentioned represents the highest hurdle to be cleared before atomic energy can become really useful as a widespread source of power.

There is one more factor which I should mention before leaving the field of power. Unless the geologists (and here one has to think primarily of the mining geologists)—unless the geologists and prospectors find us some deposits which will yield low-cost uranium, we must, if we have any hope for substantial economical power production from nuclear energy, investigate a process which is sometimes called breeding (no kin to Dr. Kinsey). This in effect means that for every atom of fuel consumed, we create more than one new atom of fuel, which in its turn can be consumed with a further creation of surpluses. This process, named in our office Operation Bootstrap, is theoretically possible, but

the margin is very slim indeed. Within 2 or 3 years we should know whether it is humanly possible to turn this dream into a reality.

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40. THE UTILIZATION OF ATOMIC ENERGY

Remarks by Commissioner Robert F. Bacher, United States Atomic Energy Commission, at a Science Conference celebrating the Seventy-fifth Anniversary of Wellesley College, Wellesley, Mass., March 17, 1949

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Since the achievements in the utilization of atomic energy seem to be primarily connected with nuclear reactors and their products, let us examine what those achievements have been in the past and what they are likely to be in the future. During the war, several nuclear reactors were built for research purposes as part of the development which was necessary in making the atomic bomb. These reactors are still in use. The nuclear reactor at Oak Ridge, Tenn., is today the central research tool of that important laboratory. It is being extensively used in many types of research and development work, and in addition is producing most of the radioisotopes which are used today in the world. The energy which this reactor develops is being blown up a large stack in the form of heated air and is thus completely wasted.

The enormous piles which were built at Hanford, Wash., during the war were primarily for the purpose of producing plutonium and are today being operated for this same purpose. During the last 2 years, there has been a program of rejuvenation of these reactors, which were showing signs of deterioriation, as well as a major construction program to make new reactors to produce more plutonium. The enormous amounts of energy which they produce are now wasted. This energy appears in the form of warm water which after suitable storage is turned back into the Columbia River and is thus of no use.

Since the war, one new research reactor has been put into operation. This reactor, which is located at the Los Alamos Scientific Laboratory in New Mexico, utilizes plutonium as its fissionable material and is a step in the study of reactors which operate with high-energy neutrons. Another reactor, somewhat similar to the one which was built at Oak Ridge during the war, is nearing completion at the Brookhaven National Laboratory on Long Island. It will be used primarily for research and development work and will provide a major research instrument for the northeastern section of the United States.

The real work in the development of nuclear reactors is now gaining headway. This work, which is carried on at many laboratories, is centered in the Argonne National Laboratory near Chicago, the laboratory in which much of the development work leading to the construction of the Hanford piles during the war was done. The development program of the Commission is built around four major reactors which are now authorized for design and construction. These are a materials-testing reactor, a Navy power reactor, a high-energy breeder, and an intermediate-energy power breeder.

The materials-testing reactor is being constructed in order to study the effects of the intense radiations produced in a nuclear reactor upon the materials used to construct reactors. One of the major difficulties of the past 2 years has been the serious effects produced upon structural materials by these radiations. This reactor, which will be able to provide these radiations at an intensity not hitherto available, should greatly advance the studies of radiation effects and lead to the development of reactors which operate at higher power.

The Navy reactor is the first attempt to provide a nuclear reactor for a specific power need. This reactor will be a land-based prototype of a unit which we hope will be suitable to drive a ship. It looks as if it would be possible to build a nuclear engine for ship propulsion which would be comparable in weight to the engine and fuel normally carried and which would provide independence in cruising radius. Such a power source for any ship is interesting and has particular applications to Navy demands. Here, again, one sees the close connection between the development of a general power source and one for a particular military need.

The high-energy or fast-neutron breeder is a machine designed to operate with high-energy neutrons, and thus contains little material which would slow down or moderate the neutrons emitted in the fission process. So far, most of the work

on nuclear reactors has been on machines which operate with low-energy neutrons. The main objectives of the fast-neutron reactor are to explore one of the very interesting possibilities of reactors—the so-called breeding principle—and to produce at least small amounts of electrical power. It may be possible to build a reactor in which the amount of fissionable material destroyed in the reactor is smaller than that produced by the neutrons emitted in the fission process. In such a reactor it would be possible to extract and use energy from the fission process and to produce more fissionable material than had been destroyed to obtain this energy. It looks as if such a machine is possible in principle. Whether or not it will be technically feasible is now being determined. If it proves to be technically feasible, the next step will be to find out whether it is economically feasible.

Another reactor, which is being designed and constructed by the General Electric Co. near Schenectady, is directed toward the production of useful electrical energy and toward the achievement of a machine, operating with neutrons in the intermediate-energy range, which is able to breed new fissionable material. Today, we know almost nothing at all about how such a machine will behave as a breeder of new fissionable material. This reactor, as well as the fast reactor, will have energy removed by the circulation of a liquid metal, thus providing heat at a temperature at which conversion to electrical energy can be achieved efficiently.

In order to get ahead with the development of nuclear reactors as fast as possible and also to provide a suitable location for these new machines, the Atomic Energy Commission has decided to establish a reactor test station in the West. This test station will occupy a large site, probably 400,000 acres, and studies are now being carried on to find a suitable location. It will need to be a remote site since many of the same requirements which apply to the Hanford site will also apply for the test station.

Two reactors now being designed are scheduled to be built at the new site, the materials-testing reactor and the Navy reactor. The site is being chosen to accommodate development reactors for many years to come, and hence must be adequate for machines far beyond these two units. With the establishment of this new site, the development of nuclear reactors, which is the backbone of the peacetime utilization of atomic energy, is now moving into a new era of accomplishment.

In addition to the nuclear reactors which are now being designed and are going to be constructed, a number of other studies of reactors for the future are being carried on. Depending upon the outcome of these studies, definite plans for construction of additional units may be formulated in the future.

Probably most exciting of these and also most long range is the development of a nuclear reactor to power an aircraft. During the past 2½ years a project to study this possibility has been carried out by the Fairchild Engine & Airplane Corp. under the supervision of the Air Forces and in cooperation with the Commission. This project is called the NEPA project which is short for Nuclear Energy Propulsion for Aircraft.

Recently at the suggestion of the Research and Development Board of the National Military Establishment, the Commission provided for an extensive review of the whole subject of propulsion of aircraft by a nuclear reactor. This review was conducted under the supervision of the Massachusetts Institute of Technology, and constitutes the most definitive assessment of the possibilities in this field. This survey, called the Lexington Project Report, is being studied and its conclusions are being used to formulate new plans for Commission work in this field.

The main part of the reactor-development program is built around the construction of units which utilize fissionable material in purified or enriched form as the fuel elements. The production reactors in use at Hanford utilize natural uranium for fuel. One of the questions now under consideration is whether a practical reactor can be constructed using natural uranium for fuel and designed to operate primarily for power production with minimum replacement and reprocessing of fuel elements. Whether or not such a unit is feasible is closely tied to the development work on reactor materials now being carried on as an important part of the reactor-development program.

The third new possible type of reactor is, in our specialized vocabulary, called a homogeneous reactor. All reactors constructed so far have been, except for one small experimental unit, built upon the principle of embedding fuel elements in other materials which are then used for cooling, reflecting, and moderating purposes. For many years the question has been studied and restudied from

time to time to see whether it would be feasible and practical to make a reactor in which these elements were all mixed together uniformly—hence, the term "homogeneous reactor." We hope that these studies can be carried further since, if they should prove successful, there is the interesting possibility that the nuclear reaction, the removal of energy, and the reprocessing of nuclear fuel could all be put together in one extended unit.

This program of reactor development is aimed at the exploration of new reactor principles. From the results obtained, we should be able to design full-scale reactors to produce electrical power in quantity. It is by no means clear at present how long it will be before such a full-scale unit is in operation, but I believe that it should be within 8 to 10 years. The development reactors now being designed should, when in operation, answer many of the technical questions. Full technical feasibility will depend upon the design, construction, and operation of a full-scale unit. Whether such a nuclear reactor for the production of electrical power is economically feasible will, of course, depend upon the nature of these new developments.

The utilization of energy from nuclear reactors has often been declared to be of little interest because there is not enough uranimum in the world to sustain an atomic power industry. This is not the case as we can easily see. If breeding of new fissionable material should prove feasible, I believe that no one would argue that the primary difficulty will be lack of raw materials.

Let us try to find whether the development of atomic power will be limited primarily by availability of raw materials unless breeding new fissionable material is successfully developed. The Engineering and Mining Journal, after consideration of prewar figures, assumes that the production of uranium-bearing ore in the world during the war exceeded a thousand tons a year of contained uraimum, although most of this uraninum was rejected as a waste by-product after the extraction of radium. Before the war there was practically no use for uranium except for the extraction of radium and for the coloring of pottery, and hence little urge to discover and mine it.

Let us assume that with some new technical improvements, it will be possible to construct a nuclear reactor in which 1 percent of the uranium which is put into the reactor is consumed. This amount corresponds to somewhat more fissionable materials that the natural uranium contains and means that some of the plutonium produced in the uranium would also be burned. I do not believe that this is an unreasonable assumption.

Let us also assume that 25 percent of the energy removed in heat can be converted to electrical energy. This is a figure which corresponds to good plant design for power stations at present. Under these conditions, with 1,000 tons of uranium available per year and a 1 percent burn-up, it would be possible to produce electrical power equivalent to 17 percent of the average electrical power production in the United States during 1947. Since the electrical energy delivered in the United States was nearly half of that delivered in the world, this means that an appreciable fraction of the world's electrical power could be produced in this way. If breeding should prove feasible, this same amount of material actually consumed would produce 100 times as much power, but I doubt if this could be done in any event for many, many years.

Actually, an intensive program of research, development, and exploration for raw materials is under way. More uranium is available today than before the war. New uranium fields are being hunted, and new methods of utilizing lower grade ores for the production of raw materials are being vigorously pursued. There seems to be little doubt that in the future uranium and also thorium will be available in greater quantities than they are today, since in the past they have been of little use.

The real problem in developing nuclear reactors as a source of energy for the future depends, not upon the availability of raw materials, but rather upon the two-stage process of first making this production of energy technically feasible and then trying to make it economically feasible. I think we can make it technically feasible. Whether or not it will become economically feasible is the real question. In this, we can only point to developments of the past where each new discovery has led to simplifications in processes and lower costs. We have a history of tremendous industrial development behind us on which we can build. I believe that the long-range future for the development of atomic energy is very promising.

41. AEC SELECTS IDAHO SITE FOR REACTOR TEST STATION

(U. S. Atomic Energy Commission, Washington 25, D. C., information for the press No. 162, March 22, 1949)

The United States Atomic Energy Commission today announced selection of an area in Idaho, including the naval proving grounds at Arco, as the best site for a new national reactor testing station. Negotiations are under way with the Navy for the transfer of the proving grounds to the Commission.

After surveying a number of sites throughout the United States, the Commission has concluded that the most suitable location for its purpose is the area in the Snake River plains of Idaho including the 173,000-acre Navy proving grounds.

The total area of the new AEC facility will be about 400,000 acres. All but approximately 20,000 acres of the desired area near Arco is Government-owned land. The new reactor testing station will compare in area with the Hanford plutonium production center on the Columbia River in Washington.

The Commission has authorized its staff to negotiate with Navy officials for the transfer and has transmitted to representatives of the National Military Establishment a request for the property, which now is in inactive status. Engineering surveys are nearly complete, but detailed boundaries for the test area have not been fixed. Other surveys are continuing to determine the availability of housing, schools, and other community facilities for personnel of the station.

Preliminary studies indicate that 75 to 100 persons reside near the perimeter of the site. The boundaries, however, are not definitely fixed, and it is the policy of the Commission to establish the station with the least possible interference with any residents.

BACKGROUND INFORMATION ON NATIONAL NUCLEAR REACTOR TEST STATION

The new national nuclear reactor testing station to be established by the United States Atomic Energy Commission will comprise about 400,000 acres. This acreage is comparable in size to the Hanford plutonium production center in the State of Washington.

The program for establishment of the reactor test station and construction there of reactors may, over a period of years, involve expenditures of several hundred million dollars. At the peak of construction 6,000 workers may be employed in building the facilities. When the station is in full operation about 2,000 employees, including scientists and technicians, may be needed.

The test station will essentially be a field facility for testing and proving for the entire national reactor development program. Research and development will continue at existing installations such as the Argonne National Laboratory in Chicago which is the major center for the reactor development program.

All AEC research units working on reactors and Armed Forces agencies concerned with military utilization of reactors will use the new facilities. Industrial groups working on reactor problems include the General Electric Co. which is designing an experimental power reactor at Knolls Atomic Power Laboratory in Schenectady, N. Y., and operates the Hanford production plants; and the Westinghouse Electric Corp., which is working on a reactor for shipboard use.

In addition to these groups, other users of the field station will be the Oak Ridge National Laboratory, Oak Ridge, Tenn.; the Brookhaven National Laboratory, Upton, N. Y.; the Los Alamos Scientific Laboratory, Los Alamos, N. Mex.; and the Hanford plant.

Activities of the station also will include the training of engineers and technical personnel of industrial and academic groups participating in the reactor development program.

Facilities for chemical processing of reactor fuel elements and for the recovery of useful material, as well as for the concentration and handling of fission products, will be provided. But reactor research laboratories will not be moved from the centers in which they are now established.

Two of the four reactors now in the design stage definitely will be located at the field station. These are the materials testing reactor and the prototype of the Navy propulsion reactor. Additional reactors undoubtedly will be constructed at the station in the future.

Reactors are the key to the future promise of atomic energy both for military and peaceful purposes. These uses include the production of fissionable material, development of power, a means of propulsion for naval vessels and for

aircraft, and production of additional radioisotopes which already are being used extensively in research and have been applied in medical therapy and industrial processes.

The size and location of the area for a test station are determined by security and safety requirements and future expansion possibilities.

Other considerations include the possibility of danger which might result from a serious accident to the reactors. It is not possible, however, for a reactor to create a bomblike explosion. The rare type of accident which might cause hazards would be in the nature of major damage resulting from sabotage or the very remote possibility of simultaneous failure of the many safeguards and control mechanisms. However, there has been no such failure since the first reactor was built in 1942 and the safety record at AEC installations has excelled all other industries.

Standards for determining where reactors could be safely and suitably built are established in consultation with the Commission's Reactor Safeguard Committee.

In addition the Commission has conducted special seismological studies and all structures will be designed to take account of such earthquake tremors as may be expected in the locality selected.

In establishing the station the Commission will endeavor to avoid unnecessarily abrupt disruption of the activities of residents who have rights in the area selected. For example, it is expected that residents having grazing rights will be permitted to continue to exercise such rights for at least the first year, and for perhaps two years, depending upon the security and safety requirements of the AEC operation.

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42. OUR NATIONAL INVESTMENT

Remarks of Wilbur E. Kelley, Manager of New York Operations Office, United States Atomic Energy Commission, before the Teachers-Inservice Course on Atomic Energy, New York, N. Y., March 24, 1949

I mentioned that a principal function of the Atomic Energy Commission was research. We have two important goals as you can see: the maintenance of our national pre-eminence in nuclear weapons, and the utilization of atomic energy for peacetime purposes. It's quite obvious that if we are to achieve either or both of these goals, we must have the best research and development talent available. Fundamental research and the development of new reactors is the principal function of the Chicago Operations Office which works with both the Division of Reactor Development and the Division of Research. However, the other operations offices deal in research, too. For instance, the New York Office, although I said its primary responsibility was the production of feed materials for Oak Ridge and Hanford, is also involved in fundamental research. We are the government contracting office for the operation of Brookhaven National Laboratory, located some 70 miles out on Long Island. We hope to make Brookhaven one of the world centers for information on atomic energy and all its ramifications. We hope to sponsor the studies of fundamental science at Brookhaven on a permanent basis, for it's from fundamental research that real progress is made in our technological way of living. Engineering is the application of fundamental science to the solution of specific problems. I'm an engineer, so quite often I belittle the fundamental scientists and they in turn belittle engineers; but we both know that we're both indispensable in our modern way of living.

The Commission maintains laboratories at almost all its production plants. These are primarily concerned with the operating problems of their parent production plants. In addition, we maintain the Argonne National Laboratory, near Chicago, with which some 30 midwestern universities are associated; the Brookhaven National Laboratory for the use of the northeastern universities; and Oak Ridge National Laboratory for the use of southern universities and for the production of radioisotopes. The accumulated information, and know-how of scientists and engineers working in conjunction with our national laboratories, represents another return on your investment.

As I have said, independent of, but coordinated with our production activities, is our research work underway across the country. Our national laboratories which I have mentioned, Iowa State College, at Ames, Iowa, Columbia University here in New York, MIT, and the University of California, in Berkeley, are some

of the places where we have important research work under way. We have two kinds of research: programatic and basic, or fundamental. Programatic research is directed toward the solution of a specific problem and in many cases is quite like engineering research. Because of its specific nature, many of our best scientists object to doing this kind of research. They feel it is a lower kind of research than basic or fundamental studies. But neither field is able to stand by itself for any period of time. We spend a good deal of time on basic research because we know that in the long run, we must have this kind of information to maintain our status in the field of nuclear science. But programatic research is what converts that basic information developed by fundamental studies into something useful. Usually, programatic research is carried out at our laboratories connected with big operating plants, although in many cases it is done in our national laboratories. Reactor development, for example, is a good example of research that is partially fundamental and partially programatic.

Basic research is typified by the work we hope to do at Brookhaven. There, we're constructing a nuclear reactor—a large graphite uranium pile—which will be used for the irradiation of some elements to produce isotopes, for the study of the action of neutrons on materials and to learn more about the mechanics of fission. By the end of June of this year, you will have invested thirty-two million dollars in the pile and other tools of research at Brookhaven and we started with an Army investment of perhaps $50,000,000. That's a good indication of what it costs these days to pursue the kind of research involved in working with atomic energy. Because the national government is probably the only source for the funds needed, we've established Brookhaven as part of our basic research program. It is operated for the government by a group of nine of the largest universities in the Northeast—Harvard, Yale, MIT, Columbia, Princeton, Johns Hopkins, Pennsylvania, Cornell, and Rochester. They operate the laboratory for no fee because of their interest in furthering the cause of education in this new field. We will make the facilities at Brookhaven available for research by qualified persons from the staffs of the schools in the Northeast, and one day, some of you may find yourselves there. We also hope to make the facilities at Brookhaven available to industrial concerns having problems in atomic energy.

There are innumerable peacetime applications of atomic energy, and we are pushing ahead to develop them. This takes a great deal of effort, and a large amount of money. We're pursuing the study of the production of power from atomic energy at the Knolls Laboratory in Schenectady, New York, at the Argonne National Laboratory near Chicago and at Oak Ridge. We have recently entered into a contract with the Westinghouse Corporation for the establishment of a new laboratory near Pittsburg to study the development of a propulsion unit which may be used on shipboard or perhaps in a submarine. It appears that probably the first real use of atomic power will be in a naval vessel. The next large possibility is a stationary power plant. Atomic power will probably be needed and used in areas where other types of power are not readily available—but areas that have potentialities for industry. As you know, towns and people accumulate and center around sources of cheap power. I say cheap power—I don't expect that atomic power will be really cheap power for some years to come, but certainly in those special localities it will be useful. * * *

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43. REMARKS BY BRIG. GEN. JAMES McCORMACK, JR., DIRECTOR, DIVISION OF MILITARY APPLICATION U. S. ATOMIC ENERGY COMMISSION BEFORE THE TEACHERS IN-SERVICE TRAINING COURSE NEW YORK, N. Y., MARCH 31, 1949

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Before any discussion of reactors for specific military purposes, it might be useful to say a few words about reactors in general.

The reactor, or pile, is a furnace in which fissionable material is atomically burned—so to speak—during the course of which burning energy is released in the form of heat and radiation.

The activity in the fissionable material is controlled so as to keep it in a state of balance. It is kept precisely at the critical condition where the neutrons from each splitting atom split one more atom, and the chain reaction goes on at a steady rate.

All the early reactors were designed either for purposes of research, or of production, or both. For these purposes the heat released in the nuclear reac-

tion is more of a nuisance than otherwise. High temperature, combined with neutron bombardment, affects the materials in a reactor in ways that are not now fully understood. In the early era of reactor development positive measures were taken in the design of these furnaces for holding down operating temperatures.

Yet, a reactor to produce power will be more efficient the higher its operating temperature, just as in the case of any other engine, fueled with coal or oil for example. Further, if the reactor is to be mobile, and again like any conventional engine, its operating temperature must definitely be high, because its size and weight will be limited. Also, and this is most important in an atomic engine, within this limitation one must allow for the heavy shielding necessary to protect operating personnel from intense radiation.

It is clear, therefore, considering the temperature problem, that building a reactor for power purposes involves in part an approach which is quite different from that which led to success in research and production reactors, although of course a power reactor will be useful also for research and production.

Because of military requirements, a major portion of the Commission's reactor development program is aimed at reactors of military interest. However, it is important to understand in this connection that when we have learned how to build a reactor to propel a ship, for instance, we will also have learned how to build reactors from which useful power may be drawn for other purposes. The impetus given to the reactor program by military requirements will result in an earlier development of power for industrial purposes than could otherwise have been the case. This situation is not new in the world of technical development; a well-known example is the railway Diesel locomotive, whose development was sparked by the naval requirement for a submarine Diesel engine.

The Armed Forces are specifically interested in nuclear reactors for the propulsion of ships and aircraft.

We would like, for instance, to have ships which can operate more or less indefinitely at sea at high speed. We would like to have aircraft whose range at high speed is not limited by exhaustion of the fuel it can carry. Nuclear power will give us these advantages when we have learned how to use it. The effort will be a large one, but the stakes are high.

As for nuclear powered land vehicles, such as tanks, the requirements are not so urgent, and the economics—even wartime economics—are not so permissive. We can emphasize this latter point by noting that a working reactor must have a critical mass of fissionable material in some conformation or another. The energy available in this mass is very large. Consider, for instance, the energy release from the supercritical mass in the bombs with whose performance you are generally familiar. Twenty thousand tons of TNT equivalent, the energy release of the Nagasaki bomb, could drive the *Queen Mary* across the Atlantic. It would take a most urgent requirement and a very rich owner to justify and permit anything like that much potential power in any vehicle. It could not be justified, for instance, in the pattern of World War II, for any land vehicle.

Considering all of the factors that can now be foreseen, it should not be many years before we have available a power plant adaptable to naval needs. I will not hazard a guess as to just how many years this may be, partly because I am not competent to make such a guess.

Building a reactor for an aircraft will be a substantially more difficult job than building a reactor for ships.

The aircraft engine field is one of really tight requirements and limitations of weight and space. The aircraft reactor is going to have to produce energy in very large quantities and be able to dissipate this energy from a comparatively small surface. It will certainly take some years before this reactor can be built; I do not know how long.

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44. ATOMIC ENERGY AND THE FUTURE OF BUSINESS

Remarks by H. L. Hull, Director, Remote Control Engineering Division, Argonne National Laboratory, Before the Third Alumni School of the Indiana University School of Business, Bloomington, Indiana, May 6, 1949

Immediately after the bombs were dropped over Japan, the utilization of atomic power was uppermost in the minds of many of our people. The astounding pos-

sibilities of large-scale energy release as compared with the amount of energy released in ordinary chemical reactions, made many of us enthusiastic and we began to plan for industrial atomic power in a matter of five years. Surely, it was reasoned, if it had been possible to produce the atomic bomb while a great war was going on, it should be possible to reduce a power "pile" or reactor to practice in two or three years.

And this might well have become a reality if "war speed" and "control" had been maintained and if short cuts had been taken. Whether or not this would have been accomplished and whether it would have been good for the atomic energy business we shall never know because, immediately after taking over, the Commission had to face the higher priority problem of keeping us well out in front in the weapons business.

There were many problems to be faced in the operation and building up of the plants for production of fissionable material—especially plutonium. A broad research and development program was initiated to back up the production program.

While it was thus necessary for the Commission to temporarily forego emphasis on the power program, it could do so with the reassuring knowledge that the fissionable material which it was producing at a greater and greater rate for possible use in bombs was the same material which might some day be used as fuel for power reactors. It was clear that with a large stockpile of fissionable material on hand we should be in a better position to develop power when and if world conditions permit. The two programs were under the circumstances not in conflict but rather tended to complement each other.

Now in 1949 the weapons business is in much better shape and the Commission can press harder for reactor development. In fact for some time the Commission has been stepping up its plans for power reactors by centralizing at Argonne National Laboratory on January 1, 1948, the responsibility for reactor research and development; by lending all possible assistance to the Knolls Atomic Power Laboratory operated by General Electric at Schenectady; and by contracting with Westinghouse Electric Corporation for the construction of a reactor for ship propulsion. More recently the Commission has announced the establishment of a reactor proving ground at Pocatello, Idaho. It is to be expected that the considerable investment in planning and in fundamental studies will now begin to pay dividends.

The prospects for atomic power have not diminished since the summer of 1945 but on the contrary have now begun to improve.

To insure an adequate nuclear fuel supply the Commission has taken steps to encourage private industry to speed up prospecting for, and mining of uranium ores. There is much activity in this field. Also there is an important fundamental research and development program leading to more complete utilization of Uranium 238 as well as Uranium 235, being carried on in the Commission's laboratories. This is known as the "breeder" program and has sometimes been referred to as "operation bootstrap."

You should definitely expect to see useful experimental demonstrations of power within five years—possibly within three. This should include a land-based prototype power plant for ship use. At the end of ten years you should expect to see these experimental power plants being productized and made commercial. After 20 years you may expect to find atomic power a growing factor in our economy.

There is no present prospect of atomic power on any scale which would appreciably affect the economy by 1960, the date of Mr. Reed's "Jackpot."[1]

You may protest that 20 years is a long time. Certainly it is! Maybe it is too long—it is however the best available estimate and it makes allowance for time to solve some very difficult problems.

When atomic power becomes practical and competitive, it will supplement power from present sources. The same distribution systems will be used. The main change will be in the boiler and fuel of the power plant. The electrical companies will have more business in their regular lines and will supply more generators and distribution equipment.

It may however develop that special applications of atomic power not presently visualized, may turn out to be the most significant. If we should indeed be fortunate enough to always have sufficient power for our regular needs from coal, oil and water, we should welcome atomic power for special needs such as

[1] "Jackpot for 1960,'" Vergil D. Reed, Nation's Business, November 1948.

development of mineral deposits in remote regions where there is no power available.

Although we cannot expect any appreciable amount of atomic power by 1960, we will no doubt benefit indirectly. New materials which will withstand high temperature and radiation must be developed for power plants. Chemical processing must be developed to a high degree. If experience is a good teacher, the knowledge and techniques learned in the solution of these and similar problems will find their way into other industrial applications.

While we are developing industrial applications of atomic energy we must not lose sight of a somewhat intangible but nonetheless important and far-reaching effect. I am referring to the pattern for industrial cooperation which will be set up as a result of AEC policies between now and 1960. The question of "how much Government control" will probably be pretty well settled by 1960.

Turning from the controversial and speculative subject of atomic power to the subject of radioactive-tracers we find a field in which there is more latitude for immediate industrial applications * * *.

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45. EDUCATION FOR NUCLEAR ENGINEERING

Speech Delivered by Maj. Gen. K. D. Nichols at Meeting of Middle Atlantic Section, American Society for Engineering Education Held at United States Military Academy, West Point, N. Y., May 14, 1949

In my talk this afternoon on "Education for Nuclear Engineering" I propose to cover very briefly the history of nuclear engineering, some of the nuclear engineering problems encountered by the Manhattan District, a few of the nuclear engineering problems presently encountered by the Atomic Energy Commission in the further development of weapons and atomic power, and some of the steps that have been taken by universities to meet the need for engineers trained to handle these nuclear engineering problems. In making this review, I hope to demonstrate that the normal engineering approach to the solution of problems is as applicable in the field of nuclear engineering as in any other branch of engineering.

In tracing the history of nuclear engineering it is very fortunate that we do not have to go back very far. It was as recently as 1896 that radioactivity was discovered. Subsequently, radium was isolated and in the 1930's notable advances in science made possible a practical and military application of atomic energy. In the 1930's Chadwick, in England, discovered the neutron, Ernest Lawrence, Berkeley, California, developed the cyclotron that made possible further advances in studying the make-up of the nucleus of the atom. Rutherford, Cockroft, and Fermi are others who made notable advances in the transmutation of elements and demonstrated the application of Einstein's law concerning the relationship of mass and energy. In all of these early experiments performed on extremely small quantities of material by relatively large and complicated pieces of equipment, the release of energy accompanying the loss of mass was of laboratory interest only. In every case the energy required to transmute elements far exceeded any release in energy due to such transmutation of elements.

In January of 1939 a startling discovery was made in Germany that made practical the atomic bomb. It was at this time that the fission of the isotope U–235 was discovered. Fortunately for us, Lise Meitner correctly interpreted the results of her experiment and, even more fortunate for us, she communicated with Niels Bohr in Denmark who in turn came to this country and discussed this startling discovery with Einstein and other scientists working here.

At this point I believe that as engineers we should recognize that here was a simple scientific discovery that had tremendous military and engineering implications and that a few scientists in a highly theoretical field not only recognized its scientific importance but its practical importance as well. In the Armed Services we are extremely grateful that the physical scientists not only recognized the military importance of their discovery but had the ability and the persistence to sell it to their government and to the military. This single scientific discovery, coupled with the conception of a chain reaction, made practicable the development of the atomic bomb and, if certain engineering difficulties can be overcome, may eventually make possible the economic production of power from the fission of Uranium 235.

The next stage in the development of the atomic bomb involved little engineering. From 1939 until June of 1942 the bulk of the work in the United States was pure and applied research, although some thought was given to the engineering problems involved in making an atomic bomb. In June of 1942 the scientific group in charge of the project, headed by Dr. Conant, decided that an atomic bomb was feasible and through Dr. Bush recommended to the President that atomic bombs should not only be developed but should be produced at the earliest practicable date. It was about this time and as a result of this decision that in the middle of 1942 engineering and production problems came into prominence.

In accordance with the President's decision to tackle aggressively the production of atomic bombs, the Manhattan District was formed to carry out all aspects pertaining to design, construction and operation of the necessary production plants. Colonel J. C. Marshall, Corps of Engineers, was the original District Engineer. Subsequent to the formation of the District, General Leslie R. Groves was placed in over-all charge of all work pertaining to the Manhattan Project.

In the early days of the Manhattan Project we recognized that our primary problems involved not only science but, even to a greater extent, engineering and industrial management. We recognized that we must see that the necessary research and development was completed, that organizations be obtained or built up to complete the design of the production plants necessary, to construct these plants and then to operate them for the production of Plutonium and Uranium 235. We also recognized that, in addition to research and development, a considerable amount of engineering was necessary if a practical bomb were to be developed. The scientists in the project at that time recognized the existence of typical engineering problems but few of them realized the complexity or the magnitude of the engineering that would have to be devoted to their solution before the project could be accomplished.

I was fortunate enough to be involved in many of the problems that confronted our organization. The first problem we had was to select engineering contractors to design the production plants. Our first selection was Stone & Webster. Although we realized that they could not handle all the problems with which we would be confronted; we needed a vehicle to make engineering studies on everything, so their original contract was made very broad and comprehensive. Shortly after the selection of Stone & Webster it was obvious to us and to the physicists in Chicago that a great deal of chemistry had to be done if a chain reaction pile for production of Plutonium were ever to be practical. In retrospect it has always amused me how a physicist assumes that chemical engineering is easy. To a physicist it is a well-known fact that it is possible to separate two elements, so as far as they were concerned whenever you had two elements that had to be separated, just stating the problem was sufficient contribution toward the solution. Owing to the general nature of the early scientific work most of our laboratories were headed by physicists; as a result, we frequently found ourselves in difficulty with chemical engineering problems.

Typical of this is the early tremendous under-estimating of the chemical problems associated with Hanford. As contracting officer I remember sitting down with the Chicago physicists, the micro-chemists who knew all there was to know about the chemistry of Plutonium which had been derived from less than milligram lots, and with engineers from Dupont. The estimate at that point was that it might take a million dollars' worth of plant to develop a practical semi-works for the chemical process. Dupont, being a little more skeptical, thought two million might be a better estimate. Inasmuch as we had the money, I suggested we use three million as an estimate. One month later Dupont was back on our necks. They had gotten into the problem enough by that time to realize that neither two nor three million would touch the problem. Not only that, they felt the whole project needed a thorough engineering review to determine if the many engineering problems involved not only in the Plutonium project, but also in the U–235 and the weapon development project, could be solved in a reasonable length of time. As a result, a committee consisting essentially of engineers was set up to review the over-all proposal. This engineering committee, which did its work between September and November 1942, outlined generally the basic engineering problems that had to be solved, made preliminary cost estimates that turned out to be resonably accurate, and recommended the types of organizations that were necessary to design, construct and operate the plants involved in the Manhattan Project.

As a result of the findings of this committee we undertook to allocate the project organizationally and to contract with the research, engineering, con-

struction and industrial organizations necessary for the complete project. Typical of the reactions of the companies selected was that of Dupont when they were asked to take on over-all responsibility for the design, construction and operation of a Plutonium production plant. I'll always remember Dr. Stine's summary of the situation when he and other members of the Dupont Company heard the report of our engineering committee, to determine whether or not to recommend to the Dupont Company that they accept their part of the project. At that time his opinion was that he foresaw no engineering problems involved in the production and separation of Plutonium that could not eventually be solved by engineering and technical talent available to the Dupont Company and other industrial concerns in the United States. He questioned very seriously, however, whether the multitude of these problems could be solved successfully in time to be of use in World War II. However, he summed it up very neatly by saying that in spite of his pessimism he saw no alternative for the United States or for Dupont than to go ahead with the project and try to solve them according to the schedule proposed.

Other companies were selected for other parts of the project. On the Uranium 235 end of the project the task involved engineering problems equally as difficult as did the Plutonium project. Here again in the Electromagnetic plant the fact that our laboratories were dominated by physicists led us into underestimating the chemical engineering involved. The basic scientific work on the physical separation of U–235 and 238 was extraordinarily well in hand, but the research on the supporting chemistry lagged behind. I well remember the days in the early production efforts of the Electromagnetic plant when no matter how much material we put into the production pipeline nothing seemed to come out the end. There were times when Ernest Lawrence was joshed by his associates for attempting to produce vanishing quantities of U–235. The quantities literally were vanishing. Here again we were faced with the single chemical problem of separating U–235 from associated gunk. Due to the small quantity of U–235 and the extremely large quantities of gunk, consisting of a mixture of many other elements, normal chemical engineering did not apply. A precision of recovery was required that far exceeded normal production standards, but production engineers, assisted by research engineers, finally devised and set up the necessary production line technique.

As a means of illustrating the need for engineers in the atomic energy field I could go on enumerating examples of how the engineering approach was used for the solution of the many complex problems confronting us. However, I prefer to draw on history only to the extent I have done in illustrating to you how the engineering approach for evaluating the task and organizing for the job was successfully applied. In this application we were assisted by the fact that we could literally draft any organization that we desired, so our only problem was one of selecting the organization and we were not confronted by what in peace time is the more difficult problem—that is, convincing the organization that it should undertake a particular effort.

Now let us take a look at the present and the future. Out of our experience in the Manhattan Project and in the planning for the development of atomic power it has become clear that the future of atomic energy depends primarily on how well engineers do their job. Let us look at some of the specific problems involved in nuclear engineering. In a pile, whether it be for production of Plutonium for bombs or for production of commercial power, the engineer is faced with new and difficult problems about which he has little experience, at least during the war he had practically none. At the present time many engineers have the experience derived during the war, but most engineers lack an educational training that permits him to solve these new problems without learning new principles required by the atomic era. Take, for example, shielding against radioactivity necessary wherever you have a chain reaction or radioactive materials. Here engineers were and are faced with strange requirements. One material might stop one type of radioactivity but not another. Moreover, some materials merely convert one type of radioactivity to another. Health physics is involved and there is little industrial background for making the necessary statistical studies. I remember well the scratching of heads in the Wilmington office of Dupont when they were trying to learn enough of basic physics and health physics to try to understand what the scientists were talking about. One aspect tof shielding is protection of the workmen. Another more important aspect is the remote control and maintenance problem. In the chemical processes, or in the working of the pile itself, the process equipment must be controlled and maintained by remote control methods. Intensive

gadgeteering was and is neecssary for doing this type of work. At Hanford complete chemical processes had to be capable not only of operation by remote control but also of maintenance by remote control. Some of the gadgetry involved is what we are now depending upon as a delaying factor in Russia's attempt to make atomic weapons. Also involved in this chemical engineering is a need for precision of recovery not normally encountered even in the light chemical industry. The value of Plutonium or U–235 is so high that extremely high percentage of recovery is necessary in any ancillary chemical process in the production of power if such power is to be competitive with other sources of power. Not only is this precision chemical engineering complicated by the need for remote control apparatus, but also the transmutation from one element to another of the attendant products is a complicating factor. The control of radioactive wastes, both liquid and gaseous, must be done to a degree not generally recognized by other industries. Many millions have been spent at Hanford in the control of these liquid and gaseous wastes, and if commercial power is ever to be practicable, even greater effort must go into this problem in order to secure an economical solution. In my opinion the chemical engineering involved in the production of power or in the production of Plutonium is the major problem that must be more efficiently solved if we are ever to have competitive atomic power.

Other related problems that require solution or perfection in the solution are in the field of heat exchange. Here we have problems that are beyond the experience of most of the experts in this field. In the heat exchange problem we are faced with the difficulty of taking a tremendous amount of heat out of a very small volume. The problem is further complicated by radioactiivty. We must consider the nuclear properties of the coolants used for transmitting power from source to machine. We must consider not only the effects of the coolant on the nuclear reaction but also the effect of the nuclear reaction on the coolant. The temperatures involved are such that liquid metals may be the only suitable coolants. When we combine all these problems with the known characteristics of materials, we find ourselves working with some very nasty materials that introduce added problems of safe handling.

Throughout the pile we are faced with engineering problems concerning materials and metallurgy. The materials used in the piles must meet functional and structural requirements and must stand up against the high temperatures involved. Not only must they stand up against temperatures for which we have little practical experience, but they must also have the proper nuclear properties. Here again the materials may effect the nuclear reaction or the effects of the nuclear reaction on these materials may be such that the physical properties of the materials, such as the structural strength, conductivity, or molecular structure, are changed to such an extent that they no longer fulfill their basic missions. Here the research engineer must work with the physicists, for a tremendous amount of work must be done to determine the nuclear properties of ordinary structural materials and to develop new materials that can be produced in quantity that have the proper nuclear properties.

In the field of gadgeteering a tremendous amount of work must be done in remote control methods. Dependable methods and equipment must be developed that are far beyond our normal industrial standards. It is costly to maintain equipment by remote control or abandon it when something goes wrong. If the economic problems of atomic power are to be solved, a greater degree of dependability must be built into just ordinary equipment than is required for any other industry.

Other engineering problems involved pertain to industrial safety. Unfortunately, many of the scientific personnel involved in the development of nuclear energy do not have practical experience in industrial safety. The result is that extremely high standards have been set. Industrial safety engineers will eventually have to solve this problem and get it on a practical scale if we are to have practical power plants utilizing nuclear energy.

In solving all of these engineering problems the solution must be based on the needs of the operator or producer. A theoretical solution is of little value if it cannot be applied on an industrial scale. The engineer, by training and tradition, is accustomed to meeting the needs of the industrial operator in like problems pertaining to other fields. The engineer has bridged the gap between the scientists and the industrialists in other engineering fields such as electrical engineering, chemical engineering, metallurgical engineering, mechanical engineering, power and others, and there is no reason why he cannot render the same service in the field of nuclear engineering.

Other engineering problems pertain to the application of radioactivity or the use of radioactive isotopes to engineering research for developing chemical engineering processes or for developing better metallurgy. Radioactive materials can also be used in the petroleum industry. Other uses undoubtedly will be developed as experience is acquired.

The problem presently confronting our universities is to determine what courses should be introduced to adequately train engineers and scientists to handle the problems pertaining to the development of atomic energy. It is not my intention to cover the needs of additional scientific training in our universities. However, as a result of my experience in the Manhattan District, I would like to make certain suggestions concerning what might be done in the field of engineering education to better qualify our graduate engineers for handling problems in the field of nuclear engineering. I do not believe that a single course in our engineering schools will be the answer. In my opinion what is necessary is the introduction of nuclear engineering courses in the main fields of civil, mechanical, electrical, and chemical engineering. Such courses in their respective fields should stress the problems of heat exchange, metallurgy and materials, chemical engineering, gadgeteering or remote control, and industrial safety, all handled from the standpoint of how nuclear physics affects the solution of these problems when applied to nuclear engineering.

Most universities have already tackled the problem of training graduates for atomic energy development. Some progress has been made. Cornell, Princeton, Chicago, and practically every other large university have introduced courses in the field of nuclear engineering or engineering physics, but to my mind too many of them have stressed the research approach rather than the engineering approach. Just as we found during the war that once the basic concept of the atomic bomb was evolved that our major problems could best be solved by the usual engineering approach, to my mind the bulk of the problems pertaining to nuclear energy must be handled by engineers who have additional training in physics rather than by physicists or chemists who have some engineering background.

I have analyzed one university's course leading to a master's degree in science, in which there is no question that they have stressed the physics, metallurgy and chemistry involved in nuclear energy. They have covered all of the scientific or research fields but they apparently have done little toward giving the student the engineer's concept of how to approach a typical engineering problem. I believe the universities are making a mistake if this is to be the main educational effort. If it is the main effort it is up to you as educators in engineering to correct this error. Greater progress can be made if we train engineers to handle nuclear problems just as we have trained chemical engineers to handle chemical problems involved in the engineering, design, construction and operation of production plants. Instead of giving a few courses in engineering to a student who is essentially a physicist, a chemist, or a metallurgist, greater emphasis should be placed upon giving students who have a basic engineering education, either civil, chemical, electrical, mechanical, or in any of the other engineering fields, the principles of physics and the problems of nuclear engineering involved in the particular field of engineering. For example, chemical engineers would major in nuclear chemical engineering, or a civil engineer major in nuclear civil engineering, each taking the necessary additional courses to qualify him for work in the field of atomic energy. The big thing we need today in the field of atomic energy is more engineers, more individuals with an engineering approach to the problem, and I see no reason why this field cannot be solved in the same way that we have made progress in other fields of engineering.

I have been fortunate in having contact with the American Society of Mechanical Engineers in their efforts to assist in this problem. In recent meetings of their Atomic Energy Committee they have discussed the need for a greater number of engineers in the atomic energy field. They have offered to assist the Atomic Energy Commission in trying to procure more engineers with industrial and commercial background for this work. More engineers and engineering organizations will be necessary as time goes on if the basic work of the scientists presently engaged in the problem is to be properly developed and applied. As an assistance in this effort, the American Society of Mechanical Engineers is preparing a glossary of all terms involved in nuclear engineering as a first step in the education of engineers. They are also entertaining the idea of making proposals for the placing of engineers on atomic energy work.

In the efforts to develop proper educational courses you undoubtedly will be handicapped by the secrecy involved in the whole atomic energy field. Owing to

the fact that the bulk of the work involved in the production of power is identical or similar to that involved in the production of weapons, this secrecy will be necessary for some time to come. The fact that practically all work is under government control is also a limiting factor. However, in my opinion, there is plenty of information available upon which an effective start in the field of education can be based. In addition, I would like to recommend that more university engineering departments should seek contracts with the Atomic Energy Commission or with its contractors for the development of the engineering research in this field. Also, more professors should seek temporary employment with the contractors and the Atomic Energy Commission, in order that they can get first-hand information about the problems involved. They will then be in a better position to determine the basic educational courses in the field of physics and physical chemistry required and the revisions and additions necessary to our more standard engineering courses, all with the idea of giving better training to the engineer in order for him to carry his share of the load in the development of nuclear energy.

In conclusion, I would like to stress again that my experience during the war and my observation of the activities of the Atomic Energy Commission since the war have convinced me that our educational efforts in the field of nuclear engineering should be devoted primarily to giving supplementary education in the fields of physics and radioactivity to engineers rather than trying to give a little engineering to scientists. The engineering approach to the problems of atomic energy will do far more towards expediting the solution of the remaining problems than the scientific approach. There is no mystery about atomic energy that good engineering can not solve.

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46. DR. ROBERT OPPENHEIMER HAPPY ON RETURN TO UNIVERSITY OF CALIFORNIA FOR SUMMER

[From the Oakland Tribune, June 24, 1949]

BERKELEY, June 23.—Dr. J. Robert Oppenheimer, 44, the noted atom-bomb scientist, is back on the University of California campus he left 2 years ago for the world scene.

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He termed the prospects of civil atomic power extremely remote and from any viewpoint extremely unimportant.

"Nuclear power for planes and battleships is so much hogwash. I think the difficulties have been underestimated."

Civil power will take a long time, enormous investments of money and the all-out cooperation of industry, he said, adding "if we can't get there in 25 years we might as well take it easy."

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"The Atomic Energy Commission has been extremely cautious," he said, adding "Like any organism, the Commission will use secrecy to protect itself.

"I'd like to see a more candid treatment of the power problem."

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47. SOME ASPECTS OF ATOMIC ENERGY

Address by Read Adm. R. A. Ofstie, USN, Member, Military Liaison Committee to the Atomic Energy Commission, Before the Volunteer Naval Reserve Units, Columbus, Ohio, Friday, June 24, 1949

POWER

A couple of years back one of the major technical societies in the electrical industry expressed real concern over the possible effect that power from atomic energy might have on the future of hydro and steam power plant expansion. This was a reasonable question then since knowledge of the new power source was just beginning to reach the public. It was at about that time, you may recall, that the more fervid writers were telling us just how many circuits of

the globe we could make in our automobile on a single charge of atomic fuel about the size of a small marble. This particular usage was admitted, in all honesty, as being perhaps a little further off than just around the corner. However, the passage of a very few years, we were told, was certain to see large aircraft, ships, and stationary power plants operating on the fission of the atom. It was concern over the latter, stationary power plants, which led the electrical group to express qualms about their own future.

Some one has expressed the view that each year the age of atomic power moves back at least two years. This is simply a case of increasing knowledge begetting a truer appreciation of the problems ahead. The fact is that there is no realistic atomic power reactor in existence today, and only recently the Atomic Energy Commission announced plans for a reactor farm in southeast Idaho which is to be the start of an experimental program in power development. The isolated location selected suggests one of the difficulties of atomic power development, namely, the danger to living things inherent in reactor experimentation.

As we well know from the wartime success of the atomic weapon program, almost anything can be accomplished if enough money and effort is put into it. Surely this holds true for atomic power, but technical problems of immense complexity must be solved before the job approaches practicality. We are working with a fuel which has an extremely high heat output per unit of size. Therefore whatever the media of heat transfer may be, gas or liquid, temperatures and rates of flow must be of a high order, far beyond anything we have encountered in engineering practices in the past. Thus new materials, new techniques must be developed before a useful and efficient nuclear power plant can be built.

Atomic power is developed in a nuclear reactor, or pile. This is a machine for containing and controlling a fission chain reaction, and thereby making energy available in the form of heat. A good analogy is the water boiler of a conventional steam power plant. But now we come to the unique element of nuclear power development, namely, the intense amounts of radiation which are produced along with the heat. This is really serious, for it poses a distinct hazard to life itself. Shielding of the reactor is therefore essential, and this presents a problem having major effect on the possible useability of the nuclear power plant. Thus getting back to our personal automobiles we would probably find that a structure many times the size and perhaps no less than ten times the weight of the conventional motor car today would be necessary just to shield the driver from the deadly rays given off from his power plant. The garage repair man, were he to work on the innards of our car, would be forced to do his job by remote control and under singularly difficult conditions. Correspondingly, in the airplane, with far greater power requirements, it may be impossible to provide adequate shielding within the weight limitations of a practical aircraft.

I think we can safely say that for these elementary reasons the atomic-powered automobile is not for us, and that the atomic airplane can only come about as the result of long extended and expensive research and happy result. I would not count on practical solutions in our day.

The mobile propulsive unit for ships and the stationary power plant present decidedly more optimistic possibilities. In both, with space and weight limitations not critical, there exists at least the physical capability of installing a useful atomic power plant. Developments demonstrating the feasibility of such plants should not be too far in the future, possibly as little as five years hence.

There is another aspect of atomic power which must be looked at, namely its economy both in setting up the initial plant and in subsequent operation. Quite aside from the developmental costs, there is the actual capital investment necessary, the very sizable quantities of extremely expensive material which must be put into the reactor, like money in the bank, if we are to get any useful return or interest on our money. Furthermore the same nuclear reaction which produces power also produces radioactive fission products which must be removed from the reactor. As in any coal or wood furnace, these "ashes" must be taken away or the nuclear fire will be smothered. But these particular "ashes" can't simply be thrown away. Not only do they contain valuable fissionable material but they are violently radioactive. They must be removed from the reactor by intricate systems of remote control, then processed chemically to separate the useful and the dangerous materials. All this involves an extremely complex problem in chemical engineering and an extensive plant for its accomplishment.

These latter factors place a basic limitation on atomic fuel as a serious competitor of conventional power sources except for quite unusual applications. It must be realized that the major cost of the electric power which runs our factories and supplies our homes lies in its distribution. Only a modest percentage is chargeable to the initial generation of power in a coal or hydro-electric plant. It is with the latter figure that our atomic installation would have to compete if based solely on grounds of cost. The atom would thus seem to be a poor prospect of displacing existing stationary power supply. It might, of course, be found worthwhile in parts of the world currently isolated from access to conventional power sources.

The mobile atomic power plant, specifically for ships, gives us a very much brightened picture. When one appreciates the very great fuel loads that are required for over ocean movements of large merchant vessels, or for long range and high sustained speed of naval units, the economy of the atom as a source of power begins to make sense. The cost of the oil fuel now used is high, it must be distributed over great distances by expensive shipping, and the vital sources are neither unlimited nor militarily secure. Now visualize the situation were atomic power available to specialized classes of naval vessels and to a substantial amount of our heavy tonnage on major ocean shipping routes such as the North Atlantic. Performance, in the sense of speed and range, would be greatly improved: to the extent, in the case of naval vessels, of vastly increasing the potential of forces afloat; and in the merchant marine, a marked operational advantage over competitive services.

The country capable of employing mobile atomic power for its shipping could benefit immeasurably. We are the first country that might be in that fortunate position, and therefore here, I believe, we shall see the first useful employment of atomic energy for power.

The Atomic Energy Commission is shortly submitting to the Congress a special report on the national reactor development program. This report explains in layman's language the fundamental principles underlying the generation of atomic power, and presents a concise statement of basic problems and the steps being taken toward their solution. I commend this paper to the attention of any who may be interested in pursuing further this subject of useful power from atomic energy * * *.

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48. AEC REACTOR SAFEGUARD COMMITTEE TO VISIT UNITED KINGDOM

(U. S. Atomic Energy Commission, Washington, D. C., Information for the Press, No. 200, August 31, 1949)

The Reactor Safeguard Committee of the Atomic Energy Commission will represent the United States at a three-nation conference on reactor safeguards and related subjects to be held in the United Kingdom from September 5 to 10, 1949. The conference will include classified discussions and inspections under the existing Technical Cooperation Program of the United States, United Kingdom, and Canada, which was established early in 1948 and does not include weapons information.

Evaluation of the potential hazards of reactors is one of the primary considerations in the location and design of reactors, and each of the three nations has carried on extensive research into various phases of the problem. Among the topics to be discussed will be environmental and meteorological studies connected with the treatment of radioactive wastes, studies of biological tolerances to radiation of plants, animals, and human beings, and the significance to reactor hazards of malfunction of reactor structure or controls, accidental error of operations, sabotage, and other action.

Members of the United States Atomic Energy Commission Reactor Safeguard Committee planning to attend this meeting are:

Dr. Edward Teller, chairman, Institute of Nuclear Studies, University of Chicago, Chicago

Dr. Manson Benedict, Hydrocarbon Research, Inc., New York

Dr. Joseph W. Kennedy, department of chemistry, Washington University, St. Louis, Mo.

Dr. Abel Wolman, department of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Dr. John A. Wheeler, Palmer Physical Laboratory, Princeton University, Princeton, N. J.

In addition to the members of the Committee the following United States representatives also plan to attend:

Dr. Frederic de Hoffman, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Commander James M. Dunford, United States Navy, Atomic Energy Commission, Washington, D. C.

BACKGROUND INFORMATION ON TECHNICAL COOPERATION PROGRAM

The Tehnical Cooperation Program is carried out under the general direction of the Combined Policy Committee, which also reviews those problems of raw-materials supply common to the Governments of the United States, United Kingdom, and Canada. The Combined Policy Committee was established early in the period of wartime development in August 1943 by the three Governments to provide broad direction to the atomic project as between the countries.

Members of the Combined Policy Committee are:

For the United States:
Dean G. Acheson, Secretary of State.
Louis Johnson, Secretary of Defense.
David E. Lilienthal, Chairman, Atomic Energy Commission.
For the United Kingdom:
Sir Oliver S. Franks, Ambassador from the United Kingdom.
Sir Frederick K. Hoyer Millar, Minister of the British Ministry.
For Canada:
C. D. Howe, Minister of Trade and Commerce.

With the passage of the Atomic Energy Act of 1946, the wartime cooperation between the three Governments had to be adapted not only to considerations of foreign policy and national defense but also in the light of the responsibilities fixed by Congress upon the Commission.

As was stated by the President in his public statement of July 28, 1949, "In January 1948 the three Governments agreed upon a modus vivendi which provided for cooperation among the three countries involving exchange of scientific and technical information in certain defined areas and collaboration on matters of raw-material supply of common concern."

The general framework thus provided has been utilized to develop technical consultations on certain specified topics, which have from time to time included visits by scientists and technicians of each country to the other two.

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49. PROSPECTS IN INDUSTRIAL APPLICATION OF ATOMIC ENERGY

By Philip Sporn, President American Gas & Electric Service Corp., on October 7, 1949, at the Annual Convention of the National Coal Association, New York, N. Y.

I

Since the first application of nuclear fission was used to destroy Hiroshima, speculation as to what that event might mean to man has gone through the whole gamut of opinion, from overexhilarated enthusiasm to dispirited pessimism. Mr. Norman Cousins, editor of the Saturday Review of Literature, expresses the belief—typical of a great many others—that atomic energy permits man, for the first time, "to emancipate himself economically." In this view, the atom will make available "resources enough and power enough for all." Kapitza, the great Russian physicist, has said that atomic energy will not become a factor in peacetime application for 50 to 100 years. But he is definitely in the minority.

Only 3 months ago the Harvard Business Review published a study which offers not only conjectures but also goes so far as to draw conclusions about the effects which atomic power may be expected to have on such specific industries as aluminum, iron and steel, rail transportation, manufacture of caustic soda, phosphate fertilizer, cement and brick, and flat glass.

The findings in the Harvard Business Review were not only extremely sketchy but the author of that article was most careful to stress their tentative character. The significance of this disclaimer can be more fully appreciated when you consider the nature of the assumptions on which the entire study is based. First, it estimates cost of electric energy generated by atomic power, at 4 to 4.5 mills per kilowatt-hour minimum and 6.5 to 7.5 mills as an intermediate range. These

figures, in turn, are based upon assumptions of costs of a nuclear power plant of $140 per kilowatt as a minimum and $230 as an intermediate estimate. Since almost no facts are available from which to determine with any degree of accuracy what the cost of such a power plant will be, it is obvious that the foundation of the Harvard Business Review discussion is not very solid.

The earliest published statement on the cost of nuclear power appeared late in 1946 in a report by Dr. C. H. Thomas of Monsanto Chemical Co. That report put the cost of a 75,000 kilowatt plant at $25 million—$333 per kilowatt.

In March of this year, Dr. Lawrence Hafstad, who had just taken office as Director of the Division of Reactor Development of the Atomic Energy Commission, said that "all of the big reactors run into lots of money." Dr. Hafstad seemed to think that the rough formula then in vogue around the Commission—"a megabuck per megawatt"—was about right.

Here, then, are responsible people using estimates which run all the way from $140 to $1,000 per kilowatt—a 7-to-1 range. For my own part I am not certain that even this range covers the outer limits on either the upper or the lower side. As a matter of fact, we do not know the sensible limits; estimates must be largely guesswork because we lack the essential facts for accurate engineering judgment.

Does this mean that we cannot arrive at a useful evaluation of the situation? Well, not quite. One thing is certain: If some day the guess at the lower limit is realized or bettered, then atomic power will have great social and economic significance. Even if we can't get the cost down to or near the lower limit, it can still have significance in places remote from economical sources of fuel or hydro. On the other hand, if costs should stay near or above the very high guesses, then atomic power is unlikely to have significance except for such applications as military craft where cost can be disregarded.

We know the general classes of engineering questions which will have to be answered before these cost imponderables can be resolved. We have been told a good deal in a general way about what is being done to get the answers. This knowledge and the various official predictions about the rate of development enable us to draw some fairly reliable conclusions about the probable timetable for atomic power. We cannot make very useful cost estimates now. We can tell now approximately when useful cost estimates will become possible.

All of this when put together in the perspective of our common knowledge about conventional power generation and utilization will make it possible for us to do considerably better than see the future through a mist of wonder, doubt, and dream.

II

Uranium 235 and plutonium, insofar as they have any future industrial application will be used as fuels. This is most important. To the best of our knowledge, although it is perhaps possible to conceive such a phenomenon, there is no known basis for believing that direct conversion of fissionable material into electric energy can be attained. Instead, we will burn uranium or we will burn plutonium; only we will burn them with neutrons.

Let's follow up this highly oversimplified view of the process. Coal which you produce, we burn in our power plants by pulverizing it and mixing it with air, which supplies the oxygen. We burn this coal and in doing so, carry out a molecular chain reaction. We end up with hot gasses and with ash. The hot gasses are used to transfer their heat to water or steam inside the boiler, and this keeps the boiler tubes from burning up. The water or the steam in the boiler might be termed coolants.

Now, as the steam reaches the proper temperature—and in a modern boiler that might be anywhere from 950° to 1050° F.—it is used to drive a turbine. Eventually the cooled hot gasses are discharged through a stack. The machine in which we release this energy is called a boiler, and the machine in which, after several intermediate heat transfers, we convert it into electrical energy is called a turbogenerator. And the modern combination of boiler and turbine, operating at high pressures and high temperature, is a most magnificent, intricate, and beautifully performing piece of plant.

As I have already indicated, if uranium or plutonium are to be used in industry, it will also have to be as fuels and they will be burned by supplying them with neutrons. The products of the combustion will be heat and hot gasses. The heat will be absorbed and the gasses will be cooled by a coolant. The coolant, in turn, will be used either to generate steam to drive a steam turbine, or to heat a gas to drive a gas turbine. The cooled gasses will be discharged through a

stack to the atmosphere. The byproduct of the burning of the uranium or plutonium will be an ash consisting of fission fragments. The machine in which all this is going to be carried on is known as a nuclear reactor. It is called that because it is the means by which the energy in the atomic nucleus is released through the process of fission.

The ash which we end up with in a pulverized fuel boiler presents a problem, but it is a problem which we know how to deal with effectively and economically. The ash developed in a nuclear reactor is highly radioactive and presents problems of infinite complexity and hazard for which satisfactory solutions are not yet known. The ash in a coal-fired boiler is by comparison a minor matter.

The gasses discharged from the stack of a coal-fired boiler present difficulties but, again, these difficulties are simple in comparison with the problem of the radioactive gasses emitted from a nuclear reactor.

In the last 20 years we have materially improved the efficiency of the steam-turbine cycle. We have raised pressures from about 1,200 to present levels of 2,100 to 2,400 pounds per square inch. We have made notable progress in raising temperatures, bringing them up from about 750° to 1050°. But it has taken us two decades to do it. One fact will give you an idea of the intricacy of this conventional steam turbo-generator: the modern boiler and turbine alone require some 27 different kinds of steel specifications, each particular kind tailored specifically to perform a particular part of the job.

The structural materials for a modern boiler producing steam at a temperature now not higher than 1,050° F. are clearly defined and are reasonably available. No one, however, can tell as yet just what materials are needed or available to meet the peculiar requirements of a nuclear reactor. The material must have reasonably low neutron absorption—so as not to quench the fire. At the same time it must be able to stand up under untried conditions of temperature and rates of heat transfer. And it must resist essential changes despite bombardment of neutrons, gamma rays, beta rays, and other products of the fission process which the nuclear reactor is designed to propagate.

I have described a rough and superficial parallelism between the steam-turbo generator and the reactor. In the case of the reactor, however, the problems which are yet to be solved impress me as very much more difficult than the by no means inconsiderable difficulties which beset the development of our modern steam generating plants. In connection with reactors there is also a special complication. A most vital factor in economics of nuclear-power generation is the "breeder." Breeding is the process—theoretically attainable, actually still to be demonstrated—by which there is produced more fissionable material than is consumed in the operation of the reactor. The major obstacles standing in the way of developing breeder reactors are of an engineering nature and are concerned with basic conflicting requirements for high neutron economy and high power output for a given material investment. There are also acute chemical engineering problems associated with the treatment of partly depleted fuel. These are problems which confront the development of all reactors—except that for breeders they are even more difficult.

But there is one caution that we must always keep in mind: However perplexing the problems of the nuclear reactor may seem, the hindsight of 1969 may well disclose to us that they were in fact simpler than they now appear.

III

What, you will ask at this point, is being done to solve these problems which must be disposed of as a prelude to any industrial application of atomic energy?

Examined from a cost standpoint alone, the effort which is being made shows up as formidable: In the fiscal year 1948 obligations amounting to $54 million were entered into by the Atomic Energy Commission on account of the reactor-development program. The corresponding obligations for the fiscal year 1949 are expected to reach a figure of $61 million, and some weeks ago the Congress authorized something over $100 million for the fiscal year 1950. A total of well over $200 million will have been committed for the 3 years 1948 to 1950 alone.

Thus, following an initial period of some hesitation and seeming confusion, the Atomic Energy Commission has now embarked on a carefully thought out program of reactor development. But, as you will shortly note, the reactors which are to be constructed under this program are all designed for experimental purposes only. None of them is intended to be capable of supplying power to drive an airplane or a ship, or the power to light a city. Reactors other than those planned for the next few years will have to be built before such

results will be attainable. But if that goal is ever to be attained, these experimental projects are the necessary point of beginning.

The program of development now under way is ambitious and broad. As described during recent months by leading officials of the Atomic Energy Commission, it consists of four reactors:

(1) An experimental reactor, intended to give information on the behavior of materials so that larger and more powerful special-purpose reactors may ultimately be built.

(2) A land-based prototype of a reactor to be used in propelling naval vessels. It will be designed specifically and solely for the purpose of producing large amounts of heat, under conditions which will permit conversion to propulsive power.

(3) A single-purpose experimental reactor, designed specifically to give information about the breeding process.

(4) Finally, the Knolls Atomic Power Laboratory Reactor. This reactor is intended to produce a really significant amount of electric power. At the same time, it is hoped that it will be able to demonstrate at least partial success in breeding.

The program, then, is designed, first, to provide for research in relation to materials. As I have already indicated, our lack of knowledge of materials and material properties is a serious limiting factor in the development of power reactors. This program is designed to remove that limitation. It is designed also to attack the "breeder" problem. And at the same time it is designed to take the first steps of producing a significant amount of electric power, although at what cost no one can as yet foretell.

Here then is an energetic, well-planned and coordinated effort—with over $200 million already appropriated to it—to solve the technological problems which stand in the way of industrial application of atomic energy. With an effort of that magnitude in progress it becomes especially relevant to consider some of the industrial consequences in the event the program of research and development should be rewarded with a measure of success.

IV

In the event that cheaper electric power can be achieved through the use of atomic energy, several industries might well be stimulated. Examples are reduction of magnesium and aluminum; refining of copper; production of cement, chlorine, and caustic soda; electric furnace operations like the production of graphite, carborundum, calcium carbide, phosphoric acid, ferro-alloys, and electric steel. All these operations are characterized by a high figure of kilowatt-hours per week per worker and a relatively low figure of wages per kilowatt-hour used.

To put it another way, power costs in these industries represent a substantial percentage of total cost—as contrasted with a relatively minor percentage in most industries—so that any appreciable reduction in power costs will materially reduce cost of product. The resultant application or use is bound to be stimulated.

Thus, in these industries we have a range of kilowatt-hours per week per worker running from a low of 2,200 for cement and electric steel to a high of 8,900 in the case of ferro-alloys, and 9,200 in the case of phosphoric acid. In these same industries we have a range of workers' wages per kilowatt-hours used from a high of 3 cents per kilowatt-hour, in the case of cement, to a low of 0.7 mills, in the case of ferro-alloys and phosphoric acid. Contrast that with figures of approximately 50 kilowatt-hours per week per worker and $1.10 of wages per kilowatt-hour used for such industries as electrical machinery, machine shop operations, and furniture manufacture.

The industries then that could benefit most from any appreciable reductions in the cost of electric energy are these which involve operations with high electrical energy consumption per worker employed. The displacement of other forms of energy by atomic energy in such industries will be indirect—atomic fuel will displace coal, gas, or oil in new plants, or in rebuilt old plants; or white coal in hydro plants that might otherwise be built.

Some new electric processes might also be developed if atomic power is cheap enough: Electric melting of general-purpose glass, for example; or direct reduction of iron by electric processes; certain kiln operations might be electrified.

Whether or not atomic power will stimulate these existing processes or encourage the developments of such new ones will depend on cost. Now what are

the major economic factors in a nuclear reactor as an electric power producer? You will recall that in a nuclear reactor, we burn uranium or plutonium with neutrons, and I am going to assume that "breeding" has been successfully developed. When that has been accomplished, 1 pound of ordinary uranium will be able to do the work of 1,500 tons of 13,000 B. t. u. per pound of coal. Under these conditions, the direct fuel cost will approach the cost of white coal—almost zero.

If the cost of generating power were dependent only on the price of fuel, here would be a power Utopia, indeed. But the processing of the fuel will involve elaborate and therefore relatively expensive chemical operations. And so, the capital costs of the chemical plant, the nuclear reactor, and the steam and electrical portions of the complete atomic power plant are bound to be the dominant portions of the cost of electrical energy at the point of generation.

Let us take a look at the cost of power at the switchboard of a coal-fired modern steam electric plant. Again I shall have to risk possible misinterpretation, and simplify.

If you start out with a modern steam plant burning pulverized coal, the range in capital costs is perhaps $150 to $200 per kilowatt. The range in fuel costs lies, say, between 10 and 40 cents per million B. t. u. The practical range in intensity of use probably lies between 50 and 68.5 percent plant factor (500 hours' use of capacity per month). Under these conditions, and using a value for cost of money of 6 percent, and allowing for depreciation and local and Federal taxes, the range in total costs of energy at the switchboard is between 5.5 and 12 mills—a range of 2.2 to 1.

For the nuclear plant, using the range of capital costs discussed at the beginning of this talk—$140 to $1,000 per kilowatt—the range in fixed costs of plant, using the same cost of money, but a higher depreciation rate, because of the more rapid obsolescence always present in a new technology, and the same taxes, would be between 3.9 and 38 mills—a range of almost 10 to 1. This wide range of estimates can't be narrowed until the present reactor program develops the data we must have for more informed engineering estimates. The total cost of electric energy at the switchboard will have to include some operating and maintenance costs and some value for cost of fuel. At best, it may be substantially zero. But the actual costs of fuel can likewise not be estimated with any accuracy until the breeding phase of the present reactor program is more fully developed.

These two unknown factors constitute the principal barrier to any sound engineering appraisal of the economics of nuclear fuel utilization: Lack of engineering knowledge on many phases of reactor design, construction, and operation—which makes it impossible to estimate the capital costs of a reactor plant—and lack of knowledge and practicability of breeding—which makes it impossible to estimate the fuel costs.

▼

What course ought the coal industry to follow in this situation? As an outsider, I would not be so bold as to attempt an answer to that question, but perhaps I can offer an analysis of the problem without appearing rash.

One way of looking at it is this: If nuclear power has such an array of formidable technical hurdles to take and if costs are so uncertain, why worry, why not forget about the entire atomic business—at least for some time to come? I don't believe, however, that any responsible person in the coal industry will forget about atomic energy, if for not other reason than that the search for peacetime application is being pressed so aggressively and will continue to be.

We have here a Pandora's box. I am sure you all recall the Promethean fable in which Pandora, the first woman made by the gods, having opened the box containing all the human ills then known, couldn't close it before this multitude of plagues escaped. But there remained one thing at the bottom of the box and that was hope. So also with nuclear energy. When the energy of the nucleus was released, it, too, brought with it a host of plagues—certainly no cities in the world were ever more plagued than were Hiroshima and Nagasaki. But it, too, left behind it hope—in fact, a number of hopes—and among these the hope of a more universally available, more easily portable, and more economical energy for the use of man. The search for it is bound to go on.

Then, is the reverse course the right one? If the coal industry has to seriously consider the possibility of atomic energy, how is it to handle the problems of expansion, acquisition of new reserves, building of new organizations? Should it consider giving up and preparing for the inevitable? Can that be the right course?

Perhaps the course in which the electric power industry has followed will be illuminating. Beginning in 1947 the industry started on a 5-year $9 billion expansion program of its facilities, unprecedented in its history, or for that matter in the history of any other industry in this country. In the 3-year period 1949–51 alone, some 18,125,000 kilowatts of new generating capacity will be completed and 15,045,000 of that—83 percent—is fuel-burning capacity, most of that coal. In working out that program, larger units, higher pressures, higher temperatures and new records for efficiency will be established. The possibility that nuclear reactors will become practical and economical devices has been reckoned with; but it has had no retarding effect on expansion plans based on the most modern technology possible today.

There appears to be every reason for belief that some day nuclear fuel will be burned in industry. But how long will it take before that actually comes about? Here you need to clearly distinguish between different possible uses. There may be, on the one hand, some limited or special application, such as propulsion of naval vessels, or utilization in areas remote from an economical supply of coal or oil. Or there may be broad applications in industry, with nuclear fuel as a direct competitor of present standard fuels—particularly oil and coal. But even on this qualified basis, the answer to this question is obviously tied up with the reactor development program under way. Let's see what some of those closely associated with the effort say.

A little over a year ago the AEC's General Advisory Committee, which includes such figures as Conant, Oppenheimer, Fermi, and Rabi, had this to say:

"If unfavorable assumptions are made about the cost of uranium and the technical practicability of breeding, the result is that atomc power would not compete with coal power in the United States except in regions where the cost of transportation of the fuel from the mine is the determining factor, or under other special conditions where the small bulk and weight of the uranium fuel are particularly valuable. On the other hand, if favorable assumptions are made about the cost of uranium and the technical practicability of breeding, the ultimate capacity may become comparable to and even larger than the present coal industry and will operate at a lower cost, at least as far as fuel expenditure is concerned. At the present time, sufficient knowledge does not exist to make a definite choice between these two alternative possibilities. It should be pointed out that, in either case, the cost of a nuclear-fuel power plant will be substantially greater than that of a coal-burning plant of similar capacity."

Then the Committee volunteered the following as to a timetable:

"Even on the assumption of a most favorable and rapid technical development along these lines, a word of caution is needed as to the time scale. We do not see how it would be possible under the most favorable circumstances to have any considerable portion of the present power supply of the world replaced by nuclear fuel before the expiration of 20 years."

Some months later this projection was further amplified by Dr. Robert F. Bacher, then a member of the United States Atomic Energy Commission, in a speech before the American Academy of Arts and Sciences:

"The present reactor development program should tell us whether it is technically feasible in a small-scale plant to produce electrical energy from a nuclear reactor. If the results are favorable, it will then then be possible to design a larger-scale reactor for the development of electrical energy and in the course of this development it should become clear whether this possibility is economically feasible. Within 8 to 10 years such a unit should be in operation. But for nuclear energy to have any significant impact upon the country as a source of electrical energy would take much longer even granting economic feasibility.

"In view of the meagerness of definite information about the long-range future of nuclear reactors, I suppose that each of us is eligible to some opinion. My own feeling is that the possibilities for benefit to man from this development of atomic energy are very great."

And in July, appearing before the congressional joint committee, Dr. Enrico Fermi, who played such an important role in the wartime development of the atomic bomb, replied to a question as to whether atomic energy was around the corner:

"The thing is not around the corner. Some limited experimental applications may be possibly not far in the future. Perhaps some naval applications may come forth in the not-too-distant future, but if my 'competitive' power you mean something that could be comparable to coal or oil, I believe that production of such huge amounts of power, if they ever will be produced, are certainly very far in the future.

"On the other hand, perhaps, one should not take necessarily a too-pessimistic view about this situation, either. There are basic possibilities; I find it really extremely difficult to strike the right note between optimism and pessimism.

"You see, we talk of a matter certainly of 15 or 20 years. Now, who is the prophet who can see things at that distance? Atomic power may ultimately develop not into a competition but, rather, in supplementation of conventional fuels.

"I believe that it would be a great disservice to engender unjustifiable hopes—I believe that it is very desirable that the public should stop thinking that atomic power is around the corner, because if they do so they are in for a disillusionment, and the public has a right to know and certainly should get a reasonable perspective of the program.

"If atomic power will develop at all into a very important industrial fact, it will do so only in a very many years. That is very clear to me.

"There might be some interesting spotty applications to this or that field to which the special features of this form of power are particularly suited. But before atomic power becomes a really large-scale affair it will take a long time."

Let me, in the light of all the expert judgment above, but in view of the fact that a good many of the problems to be solved are engineering problems, give you my own guess as to the time table. It seems to me that with all the technical problems still to be solved, the first and purely experimental phase of that program will take from 3 to 5 years. Within perhaps 3 to 5 years, after that—that means, then, in from 6 to 10 years from now—we may have a reactor producing electric power. Four to five years after that—that is, 10 to 15 years hence—we may have some commercial generation of nuclear power. But I anticipate in that time it will be commercial only in the sense that it will be operating more or less regularly day in and day out.

The recent announcement that Russia had produced an atomic explosion could conceivably affect this time table. If it results in a newly enlarged emphasis on the military aspects of atomic energy, it would doubtlessly result in lengthening these time intervals by substantial amounts. On the other hand, we have been assured that all emphasis desirable and perhaps possible has already been placed on the production of materials for atomic weapons. In the light of the above, and judging by the past good sense of those charged with formulation of policy on atomic energy development, I would expect the Russian news to have no appreciable effect on the peacetime exploration program.

As to the economic factor—when will nuclear fuel become a significant competitor of coal—please remember the two unknown factors that I have talked about. If these imponderables can be resolved favorably for nuclear power, I cannot imagine it happening any earlier than in 15 to 20, or 25 years. Perhaps it will take even a longer time. Even then, the degree of competition will depend not only on how successful the nuclear-power program turns out—but also on how successfully the coal industry can meet the ever-present challenge of advancing its own technology and discharging its social-economic responsibility.

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50. STATUS OF BROOKHAVEN REACTOR

(Background Information on Discussion at AEC Press Conference, Monday, November 28, 1949)

Unforeseen technical difficulties in design, engineering, and construction have delayed completion of the nuclear reactor at the Brookhaven National Laboratory. The new research reactor originally scheduled for completion during the fall of this year is now not expected to start operation for several months.

The major difficulties developed during testing of a new type air cooling system under simulated operating conditions. The tests revealed that the air duct work of the system as originally designed would not stand up under operating conditions, and important modifications in the design and construction of the cooling system are being made.

While alterations are being made on the cooling system, design and construction of other features of the pile, now 90 percent complete, are also being rechecked.

Testing of reactor components and construction both before and after installation is extremely rigid. It is necessary to take out all the bugs before operation

begins. To make alterations or repairs after the reactor begins to operate is extremely difficult and in some cases impossible.

Reexamination of the design and construction details of the pile is being done by scientists and engineers from Brookhaven National Laboratory, the H. K. Ferguson Co., the engineering firm in charge of the reactor construction, and Babcock & Wilcox, consulting engineers. Staff members and consultants of the Atomic Energy Commission are also engaged in this work.

The expense of reviewing the design, engineering, and construction and of making the necessary modifications in the structure will increase the estimated cost of the reactor and associated equipment by 6.5 percent over the previous estimate, from $23,322,000 to $24,827,000.

The Brookhaven reactor is designed for use for research purposes, and is similar in type to the research reactor in operation at Oak Ridge National Laboratory. Both reactors operate with slow neutrons using natural uranium as fuel with a graphite moderator to slow down the neutrons.

The designed maximum power level of the new reactor will be 30,000 kilowatts compared to 2,000 kilowatts for the Oak Ridge reactor. This fifteen-fold increase in power level has markedly complicated the problem of cooling the enormous mass of uranium and graphite.

Other modifications in the design and construction of the Brookhaven reactor have been made to provide the greatest possible degree of flexibility in operation.

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51. AEC ANNOUNCES ESTABLISHMENT OF REACTOR DEVELOPMENT TRAINING SCHOOL

(U. S. Atomic Energy Commission, Washington 25, D. C., for Press and Radio No. 218, November 28, 1949)

Oak Ridge, Tenn., November 28, 1949.—Advanced training in the field of reactor development will be given Government and industrial scientists and engineers at a newly established Atomic Energy Commission Reactor Development Training School at the Oak Ridge National Laboratory.

The emphasis on the new school will be to supply as quickly as possible scientists and engineers with formal training in reactor development. The students will fall into three categories:

(*a*) Engineers from industrial organizations who will remain on their companies' payrolls while attending the training school.

(*b*) Employees of other atomic-energy laboratories or other Government agencies detailed to Oak Ridge for training.

(*c*) Recent college graduates hired by Oak Ridge National Laboratory who will be trained as regular employees and will then be available for transfer to reactor groups throughout the atomic-energy program.

Present plans call for about 60 students to be trained at one time, about 30 students in categories (*a*) and (*b*) and an additional 30 in category (*c*). The school will operate continuously. All students will be required to have complete security investigation and clearance and the lectures and study material will be classified. Selection will be made by the Commission from qualified applicants on the basis of the need of the organization with whom its applicant is affiliated for personnel trained in reactor development, its potential contribution of the applicant to the AEC programs, and his academic record.

The shortage of trained men in the reactor development field has seriously hampered the national program for design and construction of new types of nuclear reactors. Reactors are the machines used for production of atomic energy and materials for atomic weapons.

Industrial participation is an important part of the training program since many American industrial concerns are working under AEC contracts on one or more phases of reactor development. In addition, many industrial companies of potential value to the national reactor development program have been unable to undertake work in the field because of their lack of men with the necessary training.

Plans for industrial participation are in accord with proposals made to the Commission by professional and engineering groups to provide opportunities for selected industrial organizations to send working-level engineers to atomic-energy installations for first-hand experience and training.

The Oak Ridge National Laboratory is well located for such a training school. The laboratory has also had considerable experience in operating training schools. In 1946–47 the Oak Ridge Training School—dubbed "The Clinch College of Nuclear Knowledge"—was run to provide postdoctorate training in the theoretical aspects of the nuclear sciences. Currently the laboratory is operating an educational program in reactor physics and reactor technology for its own employees.

Dr. F. C. Von der Lage, former director of the training division of the Oak Ridge National Laboratory has been named director of the Reactor Development Training School.

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52. ATOMIC PRODUCTION SPEED-UP AND SHIP REACTOR DEVELOPMENT CAUSE PROGRAM SHIFT AT KNOLLS ATOMIC POWER LABORATORY

(U. S. Atomic Energy Commission, Washington 25, D. C., for Press and Radio No. 278, April 14, 1950)

SCHENECTADY, N. Y., April 14.—Extensive revision of the research program of the Knolls Atomic Power Laboratory, Schenectady, N. Y., to provide for maximum participation of the laboratory technical staff in an expanded atomic-energy-production program at the Hanford Works, Richland, Wash., and to speed up design and development work on a land-based prototype for a ship propulsion reactor has been authorized by the Atomic Energy Commission.

The Commission's authorization follows recommendations of the General Electric Co., whose research laboratory operates the Knolls Atomic Power Laboratory, as to the best method of using KAPL manpower in speeding up the over-all atomic-energy program, in accordance with program goals set by the Commission.

The reorientation of the KAPL research followed a Commission action deferring the start of construction of the West Milton intermediate power-breeder reactor project, upon whose design the Knolls Atomic Power Laboratory has worked along with preliminary design of the ship reactor. It is estimated that from two-thirds to three-fourths of the research and development work already done on the intermediate power-breeder reactor will find use in the accelerated ship-propulsion-reactor project.

The Ship Intermediate Reactor (SIR) is a second and simultaneous attack by industrial contractors of the Commission on the problem of applying atomic energy to naval ship propulsion. The Argonne National Laboratory and the Westinghouse Electric Corp. are developing designs for a land-based prototype of a Ship Thermal Reactor (STR) suitable for naval ship propulsion. Although both reactors will be designed to meet similar Navy performance specifications, they will be separate projects, involving different approaches and therefore different technical and engineering problems.

The plans for the SIR will call for a single-purpose machine designed specifically to produce large amounts of heat to be used for generating power. This is the difference between the SIR and the original West Milton power-breeder reactor. The latter was designed both for power production and for breeding reactor fuel. The two naval reactors will contribute considerable amounts of data and operating experience which should prove invaluable in the development of future reactors for the production of power for commercial use.

The General Electric Co. has been authorized by the Commission to proceed immediately with the revised research and development program. The first step is to get engineering design work in shape to make firm cost estimates for the SIR project. After approval of reactor design by the Commission it is presently planned that the land-based prototype will be authorized for construction on a site near West Milton, N. Y. As much as possible of this work will be done on a competitive price basis.

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53. PRESS CONFERENCE, UNITED STATES ATOMIC ENERGY COMMISSION, MAY 9, 1950

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Dr. HAFSTAD. The only one that has been changed appreciably since you last heard about it is the Schenectady operation. There has been a news release on

that, as you know. Naming the reasons for the shift given, there are the increased work load for the Commission as a whole, and the fact that we needed additional help from the G. E. Co. to carry on their heavy responsibilities at Hanford. That has already been released. I think there is nothing to add to that particular statement. If you could ask a few more specific questions, maybe I can find out what is bothering you.

Question. As regards this ship or submarine reactor, I take it it is not contemplated that that would be a breeder type—that is, it will be a consumer?

Dr. HAFSTAD. I believe it has been released before, but the G. E. Co. was carrying on, simultaneously with the intermediate power breeder, a study on a naval ship reactor.

Question. Is there any less emphasis now—or is there any less emphasis foreseen—on the development of industrial power from atomic energy than was the case 9 months ago, before the Russian announcement?

Dr. HAFSTAD. I would say not. Any power reactor is a step in the direction of useful civilian power as well as military power. One could argue that a submarine reactor, specifically designed to produce really large amounts of power, would be at least as large a step in the direction of civilian power as the breeder.

We have always said that the breeding was a long-term effort, looking far into the future and touching upon the long-term supply of fissionable material. So we are still interested in breeding; we are still interested in the long-term application of atomic energy to civilian power.

Question. Will there be as much research emphasis on that, say in the next 2 years, as you planned to put on it 1 year ago?

Dr. HAFSTAD. I think the important point here is that the Nation as a whole is short of the kind of manpower that we need in these atomic energy developments. We just haven't got the manpower to do all of these things simultaneously.

What the Commission has done is to look over the needs and the priorities, and the assignments are made essentially in accord and with the priorities as they appear to the Commission. The answer to your question is No; you can't do all of these things simultaneously.

Question. Therefore, do I correctly infer that there is less manpower and effort currently in your projected plans going into industrial development than you foresaw a year ago?

Dr. HAFSTAD. It depends on just how you interpret industrial development. I would say the intermediate power breeder—which I have referred to many times as being our direct attack on that particular job, since it is used for power and breeding—has been delayed for various reasons, and in this sense I think your statement is correct: there is less effort on that particular result.

Question. What are these various reasons—the ones you outlined previously? You say intermediate power has been delayed for various reasons.

Dr. HALSTAD. I refer to the news release of April 14.

Question. Is there a target date on the development of a ship——

Dr. HAFSTAD. No. That schedule has not yet been worked out.

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54. LET US BE OURSELVES

Commencement address, by Charles Allen Thomas, Hobart and William Smith Colleges, Geneva, N. Y., June 11, 1950

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May I humbly suggest a concrete example of how atomic power could be developed in this country within the framework of our industrial pattern?

First of all, industry is interested in whether atomic energy can produce power comparable in cost to coal or water power. We know that this is not possible at the present technological stage of atomic progress. But the plan which I propose contemplates the design, construction, and operation of an atomic power plant built by industry with its own funds, producing power and plutonium in the same plant. The uranium, the necessary source of power, would be loaned or leased by the Government to the industrial plant, which would convert a portion of it into plutonium and power. The power would belong to the industry that put up the money but the plutonium and the isotopes and all the fissionable byproducts at all times would belong to the Government. Let us assume, for

example, that a 75,000-kilowatt power plant were placed in Idaho, where the power could be used in making elemental phosphorus. Phosphorus is a very important element to our national life and the present deposits in Tennessee and Florida are being depleted. However, there are ample phosphate deposits in our western territory but the deterring factor to industry is the lack of power for electric furnace operation. Let us suppose that an industry would put up its own capital for an atomic energy plant. Power and plutonium would both be produced simultaneously from the uranium fuel. The fuel, i. e., uranium, before going into a nuclear furnace, is put in metal cans which are then inserted into the reactor. This canned fuel (uranium) could be sent to the industrial plant by the Government under guard, where a small portion of the uranium is converted into plutonium. After conversion these containers are pushed out of the pile by remote control. The Government would then transport these same containers to the Government chemical plant, say Hanford, for the extraction and purification of the plutonium. Industry would receive a fee from the Government for converting a portion of the uranium into plutonium, and that fee which industry receives would offset the increased power cost. The cost of this power then would be within the range which would attract industry to make this large capital investment. Some calculations and discussions on this subject with my colleagues lead us to believe that such a plan is economically sound. Industry would get power at a price attractive enough to venture its investment and the Government would get its plutonium at a price cheaper than it is now making it at Hanford. The same bookkeeping applies in both cases. More important, we will have industry in there trying to cheapen costs, improve yields, designing low-cost plants. Thus competitive progress is made.

Several plants would then be producing plutonium. We would then have dispersed, as we are told national interests of security require, one of our most vital industries—one that means so much to our national safety. In the event of war, industry must be pulled into the atomic program. It takes valuable time to educate either military leaders or industrialists. Since time is the essence in the case of an atomic war, there may not be enough. By such a method as I have outlined, a greater segment of American industry will be well schooled in this technology. This is the American way of doing things.

It is heartening to see that the Atomic Energy Commission has cleared up one point on patents, for now if, under such a scheme as proposed, industry makes any inventions on how to cheapen the building of this plant or cheapen the processes, they are permitted to take out patents on the processes with the understanding that in time of emergency all of this information would be available to the Government.

This proposition should be open to all responsible industries who need the power and are willing to venture their capital to do it. But the Government would have to make it attractive by giving private concerns a long-term contract so that the capital may be amortized. The Government, on the other hand, must be assured that the plant and operations are carried out under their standards as to security and health. Let me bring out again that the uranium, plutonium, and other fissionable products would at all times belong to the Government. The power produced would belong to the industry. Calculations show that the capital cost for an atomic power plant today is in the order of 2½ times the cost of a conventional power plant with coal. As I have said, the fee for the plutonium would help offset the increased power cost and would result in cheaper manufacturing cost of plutonium and its byproducts to the Government. In a plan like this, it would seem that the information about design, engineering, and construction of such a plant would pass along a two-way street between industry and Government. Industrial engineers would seek Government knowledge and experience that now exists, and at the same time the over-all program of the Atomic Energy Commission would be furthered by industrial activities.

The matter of security could be amply handled, because if at any time there were any suspicions that critical materials were being misused the Government could stop the power plant immediately by stopping the supply of uranium. There is a precedent for this in the narcotic industry. Now certain chemical and pharmaceutical firms operate under Government control in somewhat the same manner. It would be understood that at all times the plant activities would be under Government inspection. Then again, the Atomic Energy Commission would not sign a contract with a company which was not reputable and proud of its own good name. If this plan was put into effect, which I think it could be, the main difficulty would be to sell industry on putting up capital. But if

the terms of the Government contract were of long enough duration and of such a nature that a partnership principle were the over-all philosophy, I believe Government and industry would mutually benefit. Each new plant would be a source of strength in peace or war.

In this way we would be promoting the useful phases of atomic energy in the same pattern in which we have made such marvelous applications of other fundamental scientific knowledge for the benefit of mankind. If the beneficial sides of atomic energy could thus be demonstrated, I believe it would be a great step forward in realizing that this new science has a good side as well as an evil one, and that this would go a long way in promoting the peace of the world. But should another war have to be, which I do not believe necessary, industry's atomic powered plants, cooperating with the military, would provide a bulwark of defense against any aggressor who would be insane enough to attempt our destruction.

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55. PROPOSAL FOR INDUSTRIAL DEVELOPMENT OF ATOMIC POWER

MONSANTO CHEMICAL CO.,
St. Louis 4, Mo., June 20, 1950.

Hon. SUMNER PIKE,
Acting Chairman, United States Atomic Energy Commission,
Washington 25, D. C.

DEAR MR. PIKE: For some time my associates and I have been studying the available information bearing upon the industrial application of atomic energy for power purposes.

The attached document sets forth in broad outline some of our ideas on this subject. I would be greatly indebted to you if you would have this document reviewed so that you can advise me with respect to the following questions:

(1) Is it the Commission's policy to encourage the development of some such program at this time?

(2) If not, what are the reasons for not encouraging such industrial development?

(3) If the Commission believes the provisions of the Atomic Energy Commission support of some such program for industry development of atomic power, which provisions of the act, in the Commission's judgment, would require amendment?

In view of the potential impact of the industrial development of atomic power on our national economy as well as on our international relations, I hope you will find it possible to have the attached plan reviewed by your staff and let me have their comments on it as well as replies to the foregoing questions at your convenience.

With every good wish,
Sincerely,

CHARLES ALLEN THOMAS.

The following proposal will, in the language of the Atomic Energy Act of 1946, "be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace."

It is proposed that American industry design, construct, and operate one or more atomic power plants with its own capital. Power and plutonium would under such a plan be produced in the same plant from Government-owned uranium.

The electric power produced would be directed by the industry to the usual end uses of power in this country, such as industrial processing, locomotion, heating, and cooling. The uranium, plutonium, and all fissionable byproducts, at all times owned by the Government, would be sent to Government designated stations for processing, storage, or disposal.

In an area abundant in natural resources but lacking adequate power, a 75,000 kilowatt atomic power plant could, for example, be designed and constructed by American industry with its own funds. Specifically, it is proposed that reactors can be so constructed that heat generated during conversion of uranium into plutonium can be transferred by a suitable liquid or gas medium into a power unit employing steam generation and steam turbines. It is be-

lieved that the necessary basic technology is largely available in the AEC, while industry is well prepared to make realistic estimates of the cost of such plants. In thus further developing and expanding America's industrial capacity, Government-owned natural uranium fuel would produce power and plutonium simultaneously.

All uranium for the power-producing operation would be on loan and sent to the power plant under appropriate guard and other security measures. The effluent from the pile would be shipped to a Government chemical plant, such as Hanford, for the extraction and purification of plutonium.

It is believed that the combined cost of making plutonium and power by the suggested means can be significantly less than by making the same quantities separately. By proper contract arrangements, industry can be offered the opportunity to use its talents for designing atomic power plants and for reducing capital and operating costs. It will not be easy to induce industry to put up the huge amounts of capital required, but if sufficient incentive is offered in the form of capital amortization programs and low power costs, it may be possible to provide power for industrial operations which cannot thrive under normal conditions and at the same time make plutonium at costs lower than those currently experienced at Hanford. In making such a proposal, we are merely indicating our belief that the waste heat from an atomic reactor can become an economical "fuel" source for a power plant and that industry can and should now consider such a technological advance on its merits as a profitable investment. At the same time, Government ought to encourage industry participating in such a program in order to reduce the cost of making plutonium and augment the supply of power for industrial operations.

It is assumed that enough fundamental scientific data and technology can be furnished by the Government to permit industry to develop engineering designs and valid cost estimates for a nuclear reactor of suitable type. It is also assumed that industrial designers would strive to reduce capital and projected operating costs by improving the technology in the traditional manner of competitive American industry. It is assumed that industrial capital would be protected through the medium of patents on improved design or operating features and that in time of emergency, Government would have free access to such features.

The opportunity to design, construct, and operate such a plant should be offered by the Government to all responsible industries needing power and willing to venture capital to obtain it. A long-term contract must be assured so that the capital investment may be amortized safely. At the same time, the Government can be assured that the plant and operations are conducted up to its standards as to security and protection of the general public. The plant activities and operations could always be subjected to Government inspection. If at any time critical materials were being misused, the Government could exercise its prerogative to stop the power plant's operations immediately by curtailing its supply of uranium or by other designated means.

Such power plant operations could be very useful to the Government in time of national emergency under conditions set forth in its contract with industry so that the latter would not suffer financial loss.

This plan avoids the criticism that critical materials such as uranium should not be diverted from military purposes at this trying time in the world's history, since plutonium would be produced for the Government for military purposes.

By making atomic power available to all responsible industries as outlined above, the Government would encourage the production of power in plants located in different geographical areas. There would thus result a dispersion of plants which is necessary for our national safety in time of emergency.

CHARLES ALLEN THOMAS.

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56. NUCLEAR ENERGY DEVELOPMENT AND MILITARY TECHNOLOGY

An Address by Dr. Alvin M. Weinberg, Research Director, Oak Ridge National Laboratory, at University of Virginia, Charlottesville, Va., July 12, 1950

My purpose this evening will be to retell a story which I suppose has been much dulled by repetition—the story of where our country stands in trying to extract something useful from nuclear fission. Of the various conceivable products and byproducts of nuclear fission—such as atomic and hydrogen bombs, radio-

isotopes, controlled power, not to speak of scientific culture, loyalty probes, and billion dollar budgets, I shall concern myself mostly with nuclear power—where it will come, when, and without being facetious, why. For even now, more than ten years since the discovery of nuclear fission, not one single kilowatt of useful mechanical energy has been extracted from uranium—at least not in this country, and so far as I know, in no other country.

The main reason we have no atomic engines or nuclear power reactors today is because it is hard to make atomic engines—much harder, it seems, than to make atomic bombs. But the technical difficulties are tremendously increased by the circumstance that, until rather recently, it was not completely clear to people connected with the effort why we—or anyone else—might really want nuclear reactors. What was lacking was motivation for the development of nuclear engines.

Briefly, it is taking a cold war to give motivation to the development of nuclear reactors for power in much the same way that it took a hot war to give motivation and point to the development of the original nuclear bomb.

But before I dwell on non-technical aspects of nuclear energy development, I should like to summarize those scientific facts about nuclear fission which explain on the one hand why nuclear reactors are hard to build, and on the other hand why it is taking the pressure of cold war to force on us so-called peacetime benefits of atomic energy.

It is simplest, in re-explaining nuclear energy, to compare a nuclear fire with an ordinary chemical fire—or if you will, a nuclear reactor with a coal furnace. Prior to December 2, 1942, all man-released energy resulted ultimately from the rearrangement of extra-nuclear electrons. When a piece of coal burns in air, electrons of carbon and electrons from oxygen undergo rearrangements which cause the release of heat, light, and products of combustion. Almost all of our energy economy has until now been based on ordinary combustion—on electronic or chemical rearrangement.

When the first man-made nuclear chain reaction was established in Fermi's knob-shaped atomic pile, mankind succeeded in causing rearrangement of the nuclear constituents of matter on a scale comparable to that involved in ordinary chemical combustion. Since the forces which hold constituents of the nucleus together—the neutrons and the protons—are enormously stronger than those which hold the extra-nuclear electrons in their orbits—it is to be expected that the energy liberated when a uranium nucleus is split is tremendously greater than when a carbon atom combines with an oxygen atom. And in fact the characteristics which distinguish nuclear fire from chemical or electronic fire all stem directly from the enormous disparity in internal energy—or tightness of binding—between the atom and its nucleus.

I have already mentioned that when an ordinary chemical fire burns it gives off heat, light, and products of combustion; in addition it requires oxygen and an original charge of fuel. In analogous fashion, when a nuclear fire burns (or when a nuclear reactor "reacts"), *it* gives off heat, a sort of light, and products of nuclear combustion; in addition it requires original fuel (U–235 or Pu) and, in a sense, *it* requires an atmosphere of neutrons rather than of oxygen. It is instructive to compare the chemical fire and the nuclear fire with respect to each of these characteristics; and to indicate which kind of energy is more convenient in each of these respects.

1. *Heat.*—With respect to heat, nuclear fire at first sight wins hands down. Everybody is familiar by now with the fact that one pound of U–235 has as much heat energy as 1260 tons of coal. As Columnist Sam Grafton once said, there is enough atomic energy in a battleship to drive a toothpick twice around the world, or something. But while nuclear fuel wins by a walk as far as its *compactness* as a heat source is concerned, it does not do so well as far as the temperature at which its heat is easily and practically available. The situation is complicated but boils down to this: materials limitations. As you know, to extract mechanical power heat must be delivered at high temperature. Practically, the temperature at which heat can be extracted from an energy-producing system—either nuclear or chemical—depends on the temperatures which the coolant and the firebox can withstand. In a furnace a fire brick is chosen only on the basis of the temperature it can stand. In a nuclear furnace, the fire brick is chosen not only for adequate thermal properties but also for adequate nuclear properties. Thus, the materials available for constructing a nuclear power system are in principle somewhat limited, and therefore just for this reason it is more difficult though probably not impossible to extract heat at as high a temperature from a nuclear reactor as from a chemical reactor.

2. *Light.*—Chemical burning is accompanied by light. If the fire is hot enough, it may give off ultraviolet light which might hurt one's eyes. Nuclear burning also gives off light but nuclear light has far shorter wave lengths then chemical light; it manifests itself as X-rays or even gamma-rays which, in the large doses given off by a nuclear reactor, are deadly. For this reason a high-powered nuclear reactor must be shielded by heavy concrete walls which add to the bulkiness and to the expense of a nuclear reactor.

3. *Combustion products.*—A coal furnace produces ashes and smoke, both of which are nuisances which however can be dealt with rather easily. A nuclear reactor produces ashes too—the so-called fission products—but these are enormously radioactive, and disposal of this waste is a problem of major magnitude.

On the other hand, certain types of nuclear reactors—such as the atomic piles at Hanford—produce plutonium, a new fissionable material, as the old kind, U235, is used up. Thus, in the ashes of nuclear combustion are the terribly deadly radioactive fission products and also the very useful new fissionable material.

The fission products tend to use up the neutron atmosphere which is required to maintain a nuclear chain reaction. It is therefore necessary to remove the fission products at regular intervals. This cleaning process is far more drastic than the cleaning of an ordinary furnace. It involves dissolving the reactor parts in acid, extracting the uranium, converting the resultant oxide to metal, and refabricating the metal into the required shapes.

4. *Atmosphere.*—A chemical fire requires oxygen to burn. A nuclear fire requires neutrons to burn. Moreover the nuclear fire supplies its own neutrons. It is in this sense that a nuclear reactor is self-sustaining or chain-reacting. The fact that a chain reactor needs so oxygen means that in principle it is possible to use nuclear power for submarines or for high altitude aircraft.

Let us summarize then the relative advantages and disadvantages of nuclear fires and chemical fires. The major advantages of nuclear energy are its fantastic concentration, its independence of atmospheric oxygen, and its capacity for regenerating new fuel as it burns its old. The major disadvantages are great expense, temperature limitations, tremendous shielding requirements—which tend to counterbalance to some extent the advantage of compactness, the nuisance and hazard of dealing with the radioactive by-products, and the need to recover and reprocess unused fuel at frequent intervals.

When one considers the magnitude of these difficulties associated with nuclear power one can hardly laugh at the following tale which appeared in The New York Times shortly after the announcement of the Hiroshima atomic bomb. It seems that on a certain planet in the solar system of the star Sirius there was a flourishing civilization of Sirius men which for many thousands of years had based its power economy on uclear energy. Great atomic piles, complete with huge shields, chemical reprocessing plants, and radioactive monitoring systems were used as central power stations. That every now and then one of these plants would blow up and spread radioactive destruction over the countryside was deemed a rather minor price to pay for the advantages of nuclear energy: its compactness, its independence of oxygen, its ability to regenerate its own fuel.

Then, under the military pressure of a planetary war, a group of scientists and engineers, after an expenditure of billions of dollars, discovered that it was possible to extract energy from black rocks that were rather plentiful on this planet. All one had to do was heat up these rocks—called coal—and they would burn brightly—without heavy shields, without deadly radioactive by-products or gamma-rays, without costly and complicated reprocessing. This new and revolutionary discovery, called chemical or coal energy, was hailed immediately as one of the most important events in planetary history, second only to the original discovery of nuclear energy. A new era was promised, an era of peace and plenty when each Sirius man could have his own little coal fire, when coal would set Sirius man free, when peace would flow from the plenty engendered by the release of chemical energy.

At the time this whimsey appeared in 1945, the atomic scientists generally laughed as hard as the next fellow. Now, five years and no atomic kilowatts later, the laughter is much less pointed. And in fact, in view of the heavy disadvantages, why should we bother with nuclear reactors. During the last war, we built nuclear reactors for definite and valid military reasons. After the first experimental reactor at Stagg Field in 1942 to show the feasibility of operation of a nuclear reactor we built an aircooled reactor at Oak Ridge National

Laboratory to produce enough plutonium for experimental purposes, and we then built the huge reactors at Hanford for large-scale production of plutonium. This was followed by several small experimental reactors at the Argonne National Laboratory and at the Los Alamos Scientific Laboratory. Since the war, no reactor of more than nominal power, excluding Pu production reactors, has been completed, although several are now under construction. No private company has invested its own money in the development of nuclear reactors for power.

The apparent post-war lull in nuclear power development has its origin in a variety of causes. In the first place, the atomic energy effort in this country suffered immediately after the war because so many of the technical staffs wanted to demobilize—to go back to their universities or industrial laboratories. The resulting uncertainty was to some extent increased by the reorganization necessitated by the transfer of the whole works from the Manhattan District to the Atomic Energy Commission. It is only within the last year or so, I believe, that the situation has settled; that the large atomic energy laboratories have been staffed by personnel who have made long-term intellectual commitments to careers in nuclear energy development; and that the permanent organizational pattern under the AEC has emerged.

But there was a much deeper reason for the post-war lull in reactor development; namely, that when the time came to ask for the many millions needed to build reactors, there were few who rose vigorously to say the country needs nuclear power reactors—reactors which are expensive, perhaps dangerous, certainly far more complicated than coal—and needs them badly enough to pay the millions required to finance them. In explanation, it must be remembered that the unfortunate pattern of international relations in which the world now muddles did not become clear immediately after the war. The pressure for development of military gadgetary such as nuclear reactors was not as great in 1946 as it is now.

And, in fact, it was precisely the demands of the miliary which have put vigor and push into the terribly difficult and expensive job of extracting useful power from uranium fission. The disadvantages of nuclear power—the radioactivity, the expense, the fuel reprocessing which make private power companies remarkably disintinterested for the time being are for certain military purposes outweighed by the advantages—compactness and independence of oxygen supply.

Two major military locomotion problems are the development of faster and longer range aircraft and faster and longer range submarines. In principle, nuclear energy should be applicable for both these purposes. Since a nuclear reactor requires no oxygen, it should be possible to adapt a nuclear energy engine to propulsion of a submarine which can travel under water for essentially indefinite periods of time. There are now two reactor projects: one sponsored by Westinghouse in collarobation with the Argonne National Laboratory and the other by General Electric for the accomplishment of nuclear submarine propulsion. The nuclear submarine project does not appear to be a particularly difficult one, at least by nuclear energy standards, and it is expected that a nuclear submarine might be in operation within a few years.

In somewhat different category stands the airplane propulsion project. If the shield weight around a reactor can be reduced sufficiently, it should be possible to construct a nuclear engine which will fit on an airplane—although a large one. Such an airplane would combine unlimited range, tremendous speed, and probably very high altitude. It would be a strategic weapon of very great potentiality. While it seems possible, in principle, to build such an airplane, the technical difficulties—such as reducing the shield weight to manageable proportions and coping with the extraordinarily high radiation and heat intensities inside the reactor—make it hardly certain that a nuclear airplane can fly. But the military advantage which accrues to the possession of a nuclear aircraft is so great that we can ill afford not to try to overcome the technical problems. A large project involving ORNL and the NEPA project at Oak Ridge, and the NACA at Cleveland, has been working for some time trying to solve the many problems connected with nuclear flight. One of the most important of the problems—the change in properties of materials inside a reactor because of the intense radiation bombardment—will be studied in the so-called Materials Testing Reactor which is being built now at Arco, Idaho—an atomic oven in which materials can be exposed to the high radiation intensity present in an aircraft reactor.

The military motivation for development of nuclear reactors comes not only from the requirement for faster and longer ranged military vehicles; it comes also from the demand for more and more nuclear fuel—either for bombs or for propulsive power. A reactor is now being built at Arco, the Experimental Breeder Reactor, which seeks to increase our supply of nuclear fuel through the breeding principle. As I previously mentioned, a nuclear reactor produces new fuel as it burns its old. If more fuel is produced than is burned, the reactor "breeds" nuclear fuel. In such a reactor, useful mechanical energy can be a by-product. Whether breeding will be successful it is too early to say; that it is an attractive path for nuclear energy development to follow seems clear.

We therefore seem to have found, in the name of military exigency, a means of financing and a motivation for the development of nuclear power. That such military motivation and military trend has emerged is in retrospect hardly surprising, though it has taken several years to make itself clear. At the end of the last war it was not realized that reactors would be as expensive as they have turned out to be and that the motivation for a $\$30 \times 10^6$ ($30,000,000) reactor project must be much more closely tied to the vital national interest than, say a $\$3 \times 10^5$ ($300,000) project if the necessary money and talent is to be forthcoming.

For our technological progress has reached such a point of sophistication that more and more we find the real obstacle to the accomplishment of a technological end to be the sheer weight of investment, both in money and skilled manpower, necessary for success. We could probably construct a rocket to reach the moon but to do so would require money which we are willing to spend only if a demonstrable and pressing national need can be served by doing so. Throughout our modern large-scale scientific technology—rockets, atomic energy, aircraft—there is this recurring aspect—that because development projects are so large, and so expensive, and so difficult, they can be financed only by the government, and then only if their motivation is a military one.

In slightly different terms, we can say that our engineering technology has progressed in certain areas to such a degree that the only user of the technology is the military. We have learned to fly airplanes much more adequately than would be needed simply for the purpose of carrying passengers from one place to another. Further development of aircraft is even more clearly motivated by military demands than was development up till now. There is today, in fact, a very remarkable, though not too well appreciated, resemblance between the atomic energy "industry" and the aircraft industry. Both depend almost entirely on government contracts, and both are concerned in greatest degree with military devices of one sort or another.

Does this mean that no civilian good will come from military nuclear reactors? Certainly not, for there are important civilian uses for compact energy sources—even extremely expensive ones.

Just to illustrate the point—should we ever reach the moon—or should we settle the Arctic—what will we use to heat the moon? A 100,000 KW power source which is small enough to put on an airplane even if it is extremely expensive will certainly find many civilian uses.

It is also probable, unless the need for nuclear weapons disappears, that nuclear energy production for civilian use will be tied to military use in much the same way that water power is tied to flood control and navigation. A nuclear TVA in which the prime justification for the power plant is plutonium production; i. e., a military justification in the national interest, but in which the by-product—power—is sold to the public, appears to me to be a very natural, an almost inevitable long-term pattern which is the consequence both of the technical realities of nuclear power and the precarious international situation which is our current lot. In such circumstances it will hardly do to compare the cost of nuclear power with the cost of coal power or water power. If plutonium must be produced, we certainly will ultimately use the by-product—power—for general civilian use.

Our present unhappy existence is a strange mixture of military and nonmilitary. Every phase of our life seems more and more to be affected by the state of half-war in which we are. It is not too surprising nor too much to wonder at that our nuclear energy effort is a military one nor that a large fraction of our total technological research and development bill is being paid out for military research and development. With whole industries such as the aircraft industry supported by the military there is little point to question the purity of motivation for atomic energy development.

Nor is this in principle a new situation. The large-scale technologies such as radio which have developed either directly or indirectly from war or from fear of war are too many to enumerate. The only difference now is that our military technologies are becoming so demanding that an increasing proportion of our *total* technological culture—increased in men and in money—is devoted to military development.

With our technology so highly developed, with it so perfected, with it so enormous in scope, it is apparent that large segments of it can be adequately challenged only by the enormously difficult and expensive demands of the military art—that without such demands, with an end to military motivation, we might expect a shrinkage of our technology for sheer lack of problems of adequate difficulty and magnitude. After all, the difficulties of making a nuclear bomber, or of detecting a high speed submarine, or of building an H-bomb, are orders of magnitude greater and involve much greater size of effort than the difficulties say of perfecting color television.

But, perhaps in microcosmic reflection of our current semi-military civilization in which the threads of peace and war are unavoidably and intimately intermingled with each other, so our nuclear military technologies are even now closely mingled with our non-military science. The national atomic energy laboratories—Argonne, Brookhaven, Oak Ridge, and even Los Alamos—which in a fundamental sense are military laboratories—are also great centers of scientific learning. Their influence on scientific culture in the regions they serve is already significant and will grow. Already the direct by-products of nuclear energy, the radioisotopes, have given much of non-military value. Already the scientific results from the nuclear military laboratories, e. g., the discovery of connection between arteriosclerosis and cholesterol have been significant in the non-military segment of our life.

We who are alive today are unhappy victims of circumstance. We see our technology—yes our civilization—being transformed inexorably into a military civilization, into a caricature pictured by George Orwell in his book *1984*. This we of the West choose as an evil which we hope is temporary but which in any case is lesser than the evil which faces us if we do not accede to this trend. The path of development in nuclear power is after all only a reflection of this larger trend. But it is by no means certain that this trend will continue always. It is presumptuous for me or for any man to claim real validity for predictions about a matter as complicated as war and peace or as nuclear energy.

Today we nuclear technologists complain of the difficulty and the expense of extracting nuclear power—difficulties and expense so great that we can find adequate support for our efforts only by appeal to the military. But it is much too early to say that nuclear energy extraction will always be expensive, will never find a place in our power economy comparable to the present position of chemical energy. Even now there are lines of research and development carried out in the atomic energy laboratories which may culminate in nuclear power which is economically competitive with coal even if it does not produce nuclear explosives as a by-product.

Today our nuclear energy effort is a military effort—as our civilization is a semi-military civilization. It is possible that tomorrow our planet will regain its senses and return to the ways of peace—that tomorrow we will look upon our trend toward Spartanism as an unpleasant fiction described only in books such as George Orwell's *1984*.

For the atom to fulfill its latent promise to man, we scientists must of course show technically that there is in the atom such promise; but we men must also bring the world out of its present chaos so that the way of the atom can indeed be the way of peace. Should we succeed in both of these—and it is wrong for me to say that we cannot—then, to paraphrase H. G. Wells—the world will be set free by the atom—but only *after* the world sets both itself—and the atom—free.

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57. TOWARD THE INDUSTRIAL ATOMIC FUTURE

By David E. Lilienthal, former Chairman of the United States Atomic Energy Commission

(From Colliers, July 15, 1950. Reprinted by permission of Collier's and Mr. Lilienthal)

The American people have been sold the biggest gold brick in our history. This brick is the notion that a few of our bright people discovered the secret formula

of the atom, a secret we can keep by locking it in a vault. It is this gold brick that has misled and frightened many otherwise steady people into thinking that the atom is a weapon and nothing else, when the truth is that here is a great new field of knowledge that can be converted to the peaceful service of humankind. It is, largely, this emphasis on "the secret" that accounts for the continuation of the present airtight Government monopoly of the industrial atom, a strange and un-American course.

Such a frame of mind as this makes it tough to get back to common sense again, but I believe it can be done. In this article I propose to suggest ways we can develop the atom as we normally would any new industrial knowledge: through private industry and competition.

Several weeks ago (Collier's for June 17) I criticized the idea of Government monopoly of information, experimentation, and development of the industrial atom. But it would smack of the demagogue if, as the first Chairman of the United States Atomic Energy Commission, I strongly condemned a course of public policy without being prepared to say what I think should be done about it. This is more emphatically true since I was among those who, back in 1945 and 1946, were unable to see any alternative to the course of Government monopoly. But on the basis of experience, experience we did not have in 1946, and in view of such new facts as the Russian atomic bomb, I am convinced that our monopoly course is no longer justified and should be drastically changed.

This does not mean abandoning secrecy about the military atom; on the contrary I believe that narrowing the area we try to keep secure will make military secrecy more effective.

We can free the atom for America's industrial genius and still maintain sensible military secrecy.

I believe in secrecy about atomic weapons, and particularly the status of their development. This is a clear necessity. But this necessity does not justify the enormous and all-embracing scope of Government monopoly of information, plants, materials, and know-how now provided for.

Government monopoly of an entire industrial potentiality is not the only way to protect and control information of military importance. Our Army, Navy, and Air Forces manage to protect secrets about their weapons and equipment without going to the extreme of establishing Government monopoly of the entire industry that produces those secret weapons.

The reasons for military secrecy as to atomic weapons are excellent ones. They are not, however, different in kind from those that apply to radar, or submarine design, or detectors of various kinds, or guided missiles, or bacteriological warfare agents.

We should, in my opinion, reshape our atomic military secrecy requirements to something more nearly resembling the limits that prevail in the Department of Defense as to all other branches of armament.

What is the best way for the people of the country to gain the full benefits of the industrial atom, and to secure those peaceful benefits as quickly as possible? This is the issue.

I believe, as do many Americans, that there are cases in which government can do a particular job more appropriately than can private enterprise. In my opinion, one illustration is the development of our vast rivers for flood control, navigation, power, and irrigation. But the industrial atom is by no means such a case.

I assert that the present course of Government monopoly is not that best way. Government monopoly is an appropriate way to provide atomic weapons and other atomic military devices. It is not, however, the way to put the atom to work for mankind. It will not put the industrial atom into the mainstream of American industry and commerce, where it can flourish.

Only industry—as proprietor and manager and investor—can do the actual job of developing industry.

Would my proposal of private development, should it be adopted, make it impossible ever to have effective international control of atomic weapons? Does the position taken in this article mean I have abandoned my views about an International Atomic Development Authority which in 1946 my colleagues and I proposed?

International, not national or private, ownership and operation of such plants as those producing uranium 235 and plutonium were indeed an integral part of our Report on the International Control of Atomic Energy. That principle is embodied in the Baruch plan as well as the plan later approved by virtually all

nations except Soviet Russia. My present proposal about the industrial atom would not bar an agreement for international control if, at some future time, the Atomic Development Authority idea were agreed upon by the nations of the world.

What needs to be done? How can American industry get the first shovels into the ground?

The broad beginning is for the country to believe that something can be done. We must stop resigning ourselves to a living denial of the things we stand for.

The transformation from Government monopoly to competitive development ought to be accomplished by a number of steps or stages. To wait until the whole change can be made in one gulp will be to wait too long.

The first definite step is to provide access to the realities of this atomic industry for a large number of Americans who are now outside the stockade.

This must be the starting point, otherwise only the inner circle will know enough to help design concrete and workable measures. That kind of help can come from the inner circle only to a limited extent. When you yourself are inside the fence, with the best of motives your zeal to admit others is not likely to be great. Moreover, it is difficult for men who are themselves well informed, at firsthand and in working detail, to understand clearly why men without that intimate knowledge are handicapped, and unable to contribute much, if anything, of their own technical resourcefulness and imagination.

The opening move, therefore, should be a complete review by the American people of our basic assumptions relating to monopoly of information in the hands of the Government and its agents, as it applies to the industrial side of the atom. I hope this article will precipitate such a review. Chairman Brien McMahon and the Joint Congressional Committee on Atomic Energy and the Atomic Energy Commission would probably welcome a fundamental reexamination of the whole industrial atomic energy situation.

Secrecy as part of Government monopoly is justified only as a means of keeping information from potential enemies. There is no sense in keeping information from our own people when it has become evident that other countries, including potential enemies, have it. We in this country are suspicious of secrecy, with good reasons. It has been used as a screen behind which officials can pompously hide blunders and ineptitude, and protect themselves from legitimate criticism. And it has been a way to caress the ego of the holder of the secret: "If you knew what I know."

Equally or more serious is the fact that, in a situation such as I am discussing, secrecy is hard on our own technical progress, our own headway; and its cost in dollars is staggering. Foy Kohler, an American who spent some years in our Embassy in Moscow, reports that in Russia "it takes about two to do a single job—one to work and one to watch." Anyone who has seen the atomic enterprise from the inside will get a wry smile from his remark, though our ratio is certainly not that high. Not yet, anyway.

A mere reading of the sweeping words of the present law conveys some idea of the breadth and extent of the Government's hold. But the situation in practice is even worse than the words might indicate.

Under the Commission's wartime predecessor, the Manhattan District, everything about atomic energy, including the very existence of such an undertaking, was declared officially secret. It was "classified" or "restricted" information.

"Secret" was stamped on virtually everything, even on Manhattan District books and periodicals, of which identical copies were also available to the public on the shelves of almost every technical library in this country—and Russia. "Secret" stamps, creating a Government information monopoly, when on almost every last thing of an atomic industrial nature done during the war, even on some equipment that was well-known and commonplace. And I have seen intricate gadgets, stamped "secret" by the Manhattan District, that could have been purchased by anyone right off the shelf in hundreds of stores in this country—some of it as Army surplus!

So the Atomic Energy Commission on January 1, 1947, inherited a huge undertaking in which, for asserted military reasons, virtually everything, even of the most common or innocent character, was hush-hush. An ordinary screw driver of the kind you can buy at a dime store, used to tighten a screw in an assembly involving atomic materials, was treated as "restricted data." Under the atomic energy law it cannot be handled, or even seen, by any person who has not been investigated by the FBI and cleared by the Commission.

This is palpable and costly nonsense. But as a matter of practical operation it is not untypical. Such a state of affairs does not serve to increase the respect

men feel for their work; but this condition is well-nigh inescapable as things now stand.

Take, for example, last summer's incredible congressional hearings on charges of "incredible mismanagement" of the atomic enterprise. The best managerial and technical brains of a great industry had to be away from their work day after day so they could explain to a Senator (under klieg lights and before television cameras) such things as how a chip of uranium got into one of their workmen's socks. For, under the monopoly law, that chip of uranium—out of tons and tons handled every month—is treated as "restricted data."

Is it any wonder, then, that American industry looks upon the development of the industrial atom with such coolness? I have talked this over, at length and often, with scores of our ablest industrial executives and research directors. Almost to a man they asserted that what may be one of the greatest discoveries of modern times simply will not and cannot be fully developed by American industry under the strange, artificial, emotion-charged and Government-dominated conditions that now exist. I agree with their position. All of us are losing a great opportunity each day these conditions continue.

The Commission is authorized to "declassify," that is, remove a piece of information or equipment or material from this hush-hush category. But this can be done legally only upon a finding, by the Commission, that the data may be published (which means, opened to the public generally) without adversely affecting the common defense and security.

In practical operation this is ineffective and unworkable as a means of furthering, on a broad front, the great potentialities of the industrial atom by American business. Thousands of pieces of information have in fact been declassified by the diligence of the Commission, though largely in scientific rather than industrial or technological areas. But industrial men get little stimulus from such a patchwork, bit-by-bit approach to their possible interests, so remote from physical reality.

If the only way to crack the monopoly of information is this declassification process, it simply will not be cracked. The record to date is the best evidence of that fact.

The McMahon Act includes a provision that provides a clue to what, in my opinion, should become general policy as to dissemination of industrially useful information.

The law declares that the policy of the Commission should be that "the dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that *free interchange of ideas and criticism* which is *essential to scientific progress*." [My italics.]

Here is a recognition by Congress of a salutary principle. It should be extended to industrial information.

Science was dealt with differently in this respect from engineering and industrial knowledge because the scientific community of the country was able to persuade Members of Congress that the real atomic secrets were in the area of what was called technical know-how, not in scientific knowledge.

This distinction, however, between science and technology, will not stand up. As almost every man with industrial development experience will agree, there are few tricks of know-how that cannot, independently, be approximated or duplicated by other competent men.

(I do not include in this present article my views as to the effect of Government monopoly on fundamental science and of the role of universities and research institutions, the discussion here being directed to the business side of the atom.)

So I would urge, as a basis for public discussion, that the revised law say in effect: Atomic military information is not different in kind from the information about the secret military aircraft that carries an atom bomb or the secret fighter plane that protects it.

But other changes in law or in practice will also have to be made before American industry can take hold of the industrial atom and begin to develop its potentialities in a competitive climate. Thus, it is essential, for example, that the scope of supervision now exercised by the Congress be confined (as under the Constitution it should be) to broad policy matters; and the spirit in which a great technical venture is dealt with by committees of Congress needs to be changed.

Assuming suitable changes in the law and in the attitude of the public and of the Congress, how can private industry get started?

First, as to the great factories producing uranium-235 and plutonium. For practical and temporary reasons I would recommend no immediate change in

their ownership or operation, though immediately leasing them to the private concerns now operating them under contract has much to commend it.

But, without delay, other outstanding industrial concerns should be fully informed about the nature of these plants and their processes; they should be asked to prepare their ideas for improving processes and designs for future plants, or for replacing the present methods. Competition in new ways of producing these materials should be encouraged rather than forbidden, as is now the case.

The private companies operating these plants as contractors would welcome competitors in the field; for, as the General Electric Co. (one of the major operators) has put it, "The economy that does most to foster competition is the one that makes easiest the establishment and growth of business."

Private investment in such production plants is not out of the range of future possibility, though the amounts are huge. The Government would, of course, continue to receive that portion of the total output needed for the bomb program.

But a more important and creative opportunity lies in the designing and the building of atomic machines by private concerns, with their own funds. One is a machine called a reactor, to produce electric power, which might also produce plutonium while it produces power. The second is a research reactor for the intense irradiation of metals, pharmaceuticals, glass, fibers, oils, and so on; in short, a wide range of exploration for industry. The third is a reactor and plant to produce and process radioactive isotopes or tracers, already widely used in medicine, in industry and agricultural research.

Private capital for investment in such machines, and for experimental and development work generally, would be available if the climate for private enterprise in this area were made reasonably healthful; that is, if it met the requirements of almost any pioneering business undertaking.

This will require changes in a good many provisions of law, in my opinion. But more important by far than particular legal changes is a complete change in the way we approach the industrial development of the atom—a change from the Soviet to the American style.

As to particular legal changes, I suggest they should include the following:

(1) A firm, clear, and unambiguous policy, the declared purpose of which is to get the industrial atom into the invigorating stream of American competition. This policy should be written into law and lived up to in spirit.

(2) A reasonable prospect that, if the financial risks are assumed (and these would not be inconsiderable), those who take the risks would stand to benefit if their investment of money and effort succeeded.

A change in the basic policy of atomic development would carry with it the necessity for a complete revision of the patent provisions of the present law, to make them conform (as they do not today) to the principles of the American industrial incentive system.

(3) Section 7 of the McMahon Act contains an explicit invitation to the exercise of a political veto over scientific and industrial advance. This must be eliminated before we can hope for private development.

This astounding section provides that whenever "any industrial, commercial, or other nonmilitary use of fissionable (atomic) material or atomic energy has been sufficiently developed to be of practical value, the (Atomic Energy) Commission shall prepare a report to the President stating all the facts with respect to such (nonmilitary practical) use, the Commission's estimate of the social, political, economic, and international effects of such use and the Commission's recommendations for necessary or desirable supplemental legislation." After the President has sent this report to Congress with his own recommendations, Congress has a period to debate whether this "industrial, commercial, or other nonmilitary use * * * of practical value" may proceed, or whether Congress should forbid it. This is one of the most appalling reversals of our way of doing things in this country of which I have any knowledge.

If such a veto of industrial advancement had been in the lawbooks when the locomotive was first developed, the outcry of its competitors, the stagecoach and the canal, might well have barred the progress of our railroads.

It may be that Congress intended that this industrial veto power was to apply only to developments in Government-owned facilities. But no prudent lawyer could assure an industrial concern that this is the correct interpretation. Hence, until this provision is repealed or clarified, no businessman is likely to invest his own money to begin experimentation with the industrial atom leading to a commercial application.

The precedent of this particular provision of the Atomic Energy Act ought to be buried fast and buried deep. If it were followed, and came to fasten itself upon us, it would spell the end of a dynamic America.

To these three conditions a fourth might be added:

(4) Considerations ought to be given to the granting of allowances, in corporate taxes, for concerns who pioneer with their own money in atomic research and development work that is now being carried on out of public funds. Other inducements, such as special depreciation allowances or the joint investment of private and public funds or matching of such funds, may appear desirable.

Atomic reactors, heretofore built for the Government with public funds or now under design, cost millions of dollars. Whether reactors need to cost nearly so much is one of the important things industrial competition will probably establish.

One such experimental reactor I have suggested for private investment would produce electric power, but is so designed that it will also produce plutonium as a byproduct. The builder of the reactor would use, or sell, the electricity. An example of an opportunity for such an operation is phosphate fertilizer production, using the electric furnace method, in the power-short Idaho-Utah region that is rich in phosphate ore. Aluminum production, which requires great amounts of electricity, preferably near the supply of bauxite, might prove to be another such example.

The important thing about the building of such a reactor—important for the country as well as industry—would be this: For the first time an atomic industrial machine would be built with the builder's own money.

The first breath of the tonic air of competition would blow through the atomic industry. With its own dollars—not the Government's—at stake, industry would assign its very best men to these tasks. The heat would be on. The industrial atom would really start to roll. This would not be wholly because of the pressure of costs and the desire for profits. The fun would be back in this particular venture, the wartime hangover of "cost plus" would ease off; pioneering gumption and a sense for costs would return.

The second atomic machine I recommend as a beginner might well be built in the proximity of a metals center such as Pittsburgh or Detroit or Cleveland, or adjacent to a great phermaceutical or chemical area such as Chicago or Detroit or St. Louis. It would not be for power generation, but for research and development to observe the effect of radiation on scores of industrial materials.

Here the industrial meaning and possibilities of radiation's power to change the very nature and structure of matter could be dug out, and worked over, and turned to useful ends.

But it would probably be from the process of designing and actually building and operating these reactors that the greatest benefits would flow. Industrial engineers and development men don't ordinarily learn things by reading a "declassified" document; they learn by trying things; trying them out themselves.

In the considerable job of actually creating these reactors, finding materials that will perform under these new conditions, getting the "bugs" and the high costs out of them, as well as in using them day by day, ideas would start rising all through American industry even as life stirs under the spring sun after the long dormancy of winter.

The building of these reactors by private industry would, of course, require substantial amounts of atomic materials. Reliable American companies ought to have a right to buy and to own such materials in any amount reasonable for research, development or power purposes. The law might specify as a ceiling the maximum percentage of the total supply of uranium which should be in private ownership, but certainly if that percentage is fixed conservatively that material will do at least as much for the national security if used for developing the industrial atom as would the same amount in atomic or superatomic bombs.

The Government, of course, should keep close track of all atomic materials owned privately. And, of course, the Government's right to take possession of any private atomic material at any time, paying compensation afterward and not as a precondition, ought to be made part of each sales transaction.

A third reactor that could be built by private business would resemble, in purpose, the machine now in operation at Oak Ridge, for the production of radioactive isotopes, or tracer atoms. In this machine almost any common article can be inserted—salt, steel, phosphorus, iodine, and so on—and when it comes out it is radioactive.

A large market demand for these radioactive tracer products has already been built up. They are being manufactured today by the Commission and sold to hundreds of the country's research laboratories and medical centers.

The Commission's forces have done a fine job in promoting the uses of these tracer isotopes, and in improving the technical side of the operations. Competition would be welcomed on all sides. The present Government price scale presents a problem, but not an insoluble one.

The main and most often-heard arguments against the position I am taking I do not find persuasive. Here they are:

First is the argument that we need Government monopoly as a means of protecting the secret of the atom bomb. This argument is carried so far as to maintain that secrecy about weapons is impossible without Government monopoly of information over virtually the whole enterprise in all its industrial aspects. As I have already indicated, this argument does not persuade me, and particularly not since the Russians succeeded in making an atomic bomb.

There was a time when one could hope that the Russians might never be able to produce atomic materials suitable for an atomic bomb—that is, on a production, not on a laboratory, scale and of the requisite high purity.

But the Russians have made and tested an atomic bomb. We must assume that they had at their disposal adequate technical information. More important even than information, they must have men with the technical skills required to factory-produce atomic materials, as well as to produce a bomblike explosion.

The scientific and technical information furnished the Russians by the atom spy, Dr. Karl Fuchs, we know to be extensive and vital. Without men able to translate such information into industrial operations, however, this alone would not have been enough.

These new facts from Russia should certainly make all of us take a fresh look at our reasons for Government monopoly.

Everything considered, my conclusion is that the present scope of Government monopoly and secrecy hurts us more than it helps us.

Second among arguments against freeing the atom is the contention that only the Government can undertake the development of the industrial atom because private capital is not available for this purpose. Here is a genuine difficulty which can, I believe, be overcome by the steps I have suggested in this article.

Third is this argument: Atomic energy is an asset that belongs to all the people of the United States. The money of the whole people made the discoveries possible, built the plants and laboratories. The people carried the risk of failure, and they should be the ones to benefit, not private corporations. Furthermore, atomic energy is so overwhelmingly powerful a force for good that it should not be put in the hands of any private organization.

The Government alone is big enough and responsive enough to the whole people for so great a trust as this. Moreover, the hazards to human life and health in the use of atomic energy in industrial activities (such as power production) are considerable and still largely unknown. There is greater protection against these hazards in exclusive Government ownership than could reasonably be expected of private corporations. But the same rigid standards Government now prescribes, as proprietor, could be made effective without Government monopoly, and enforced through inspection.

What we all want is that the people should get the greatest possible benefits from atomic energy as quickly as possible. After considerable experience and observation, my own conclusion is that the people will benefit most and soonest by freeing the atom, not by fencing it in behind the walls of Government monopoly and by leaving its development in the hands of a limited number of corporations, contractors of the Government, with all outside competitors barred.

I am under no illusions that the change from Government monopoly can be made without difficulty or without loud outcry. For there is much emotion wrapped up in the atom, and there already are governmental vested interests that have staked out a claim. But I have confidence in the outcome. For free competition is right in character for a people who cherish their pioneering heritage and live in its spirit.

I believe we shall Americanize the atom.

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58. THE ADMINISTRATION OF THE ATOMIC ENERGY COMMISSION

Remarks of Gordon Dean, Chairman, United States Atomic Energy Commission Before the State Bar of California, at Los Angeles, Calif., October 6, 1950

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While there are many interesting phases of the Commission's work, I think that in a gathering of lawyers concerned with administrative law it is appropriate that I discuss with you the scope of the regulatory powers of our agency.

These might be grouped roughly under four headings: First, regulatory powers which are of importance in the development of the atomic-energy industry; second, those regulations which pertain to the field of patent law; third, those regulations dealing with the field of security; and fourth, the contract appeals system.

The framers of the Atomic Energy Act recognized that they were writing legislation for a completely uncharted field. They were, therefore, very mindful of the problem of controlling dangerous potentialities. Thus many of the most important regulatory powers granted to the Commission are analogous to those long exercised by other agencies of the Government concerned with dangerous or potentially dangerous instrumentalities, such as munitions of war, drugs, explosives, and the like. Some of the items with which the Commission must deal are dangerous in themselves; for example, highly radioactive isotopes and poisonous plutonium. Other items, while perhaps not dangerous in themselves, may become so when used in a dangerous manner, either from the standpoint of public safety, as in the case of uranium in a poorly designed reactor or from the standpoint of national security as in the case of our weapons facilities.

The most far-reaching perhaps of all of our regulations deals with the control of what we refer to as "source materials"; that is, uranium and thorium which are the fuels of the atomic energy industry. These regulations are based primarily on section 5 (b) (1) through (4) of the act.

Briefly, the regulations require a license for every transfer, delivery, receipt of possession or of title to, or export from the United States of "source material" after removal from its place of deposit in nature. The term "source material" is so defined as to include within its meaning any material, except fissionable material, which contains by weight one-twentieth of 1 percent or more of uranium, thorium, or any combination thereof. In keeping with the experience and practice of other regulatory agencies, licenses issued by the Commission under this regulation are of two basic types: General, such as those issued to commercial or contract carriers, druggists, or physicians, and specific licenses which are issued to named persons in response to applications filed with the Commission.

At the inception of these regulations, the traffic in uranium and thorium ores and refined products occupied the attention of only a small number of business firms and individuals. Hence, the Commission's job of maintaining regulatory control over the industry has been a relatively simple one. Since the regulations were issued on March 17, 1947, some 3,600 specific licenses have been issued. Of these 800 were for export, the majority of which were for small quantities of thorium, either as thorium nitrate for chemical analyses or in the form of mantles for incandescent gas lamps, much in demand in parts of the world where electricity is unobtainable. The greater part of the movements of uranium and thorium are, of course, those under the direct control of the Commission or its contractors in the main production channels.

Another category of regulations is that having to do with our production facilities.

On November 20, 1947, the Commission issued a regulation pursuant to section 4 (e) of the Atomic Energy Act which requires that an export license be obtained from the Commission for named items of equipment, defined in the Atomic Energy Act as "facilities for the production of fissionable material." This regulation at present is primarily an export control regulation. It prohibits the manufacture, production, transfer, or acquisition for export, as well as export itself, of such facilities except pursuant to a license issued by the Commission. As with the source material regulation, licenses are of two basic types, general and specific. In this case, however, the general license authorizes completely free domestic manufacture, production, and transfer of one class of facilities. In this class are many of the highly important component parts which go to make up the plants in which the Commission produces fissionable material (excluding, of course, any classified types of equipment) such as Geiger counters, mass spectrometers, leak detectors, ionization chambers, electronic tubes, high vacuum pumps and certain large electronuclear machines such as Vandergraaf generators. It is the aim of the regulation to interfere as little as possible with the manufacture of these items for domestic consumption and, in fact, such interference is limited to a reporting requirement. The Commission in carrying this program has the assistance of an industrial advisory group, which affords an excellent means of exchanging ideas between the Commission and the affected

industries. A different atmosphere prevails in the control exercised over the export of such facilities—for reasons which are obvious—and exports may not be made under the regulation except with the specific license of the Commission in each case. The controls on export established in this regulation are supplemented by the Department of Commerce.

Perhaps the best known of the Commission's regulatory-type activities which affect the development of an atomic energy industry is the system for distribution of radioactive isotopes produced in AEC reactors. The choice of the term "regulatory type" is deliberate, for in this field, despite a grant of authority in section 12 (a) (2) of the Atomic Energy Act to regulate this field, the Commission has found it possible to protect health and property without formal regulations. It is done through contractual agreements with users of isotopes, coupled with a growing system of close cooperation with national, State, and local agencies possessing regulatory power in the public health and safety field. Thus far the Commission has not issued formal regulations under section 12 governing the use of radioisotopes.

The most important substance in the atomic energy field is fissionable material—that is U–235, plutonium, and U–233. Fissionable material is the material from which weapons are made and which may serve us some day as fuel for economically feasible power production. The duality of its uses—as explosive or as fuel—essentially determines the characteristics of the regulatory power vested in the AEC to control its distribution. Thus, the Atomic Energy Act empowers AEC to regulate such distribution, under rigid terms designed to insure the common defense and security, and at the same time establishes standards which encourage such distribution in the interest of developing beneficent uses. The keystone of control is Government monopoly of all practicable methods for producing fissionable material in quantity, coupled with exclusive Government ownership of all fissionable material however produced. Having thus established Government ownership of the material, the Atomic Energy Act, in section 5 (a), prohibits its possession or transfer, except as authorized by the Commission; directs that it shall be distributed in such quantities and on such terms that no applicant will be enabled to obtain an amount sufficient to construct a bomb or other military weapon; and further directs that the AEC shall not distribute material to any applicant, and shall recall any distributed material from any applicant, who is not equipped to observe, or who fails to observe safety standards to protect health and to minimize danger from explosion or other hazard to life and property. This distribution system here envisaged is one of the regulatory activities which still lie ahead. To date AEC has not seen fit to distribute fissionable material to any applicant, reserving the Nation's supplies entirely for direct AEC use.

Another regulatory power of the Commission which is provided for in the act is one which grows out of the recognition by the Congress that at some time the Commission will be faced with the problem of arranging for the distribution of power from nuclear reactors.

The most striking characteristic of AEC regulation in this field is that it does not yet exist, primarily because it awaits the solution of scientific and engineering problems which are still ahead of us. Thus, the distribution of byproduct power, which will someday almost certainly form a significant block of the energy resources of this country, is an academic problem—and will remain such until nuclear reactors have been built, and rebuilt, to produce such power competitively, at least in special applications, with other energy-releasing equipment. Suffice to say here that byproduct-power distribution when it comes, is to be carried out by AEC under section 7 (d) of the act which provides:

"If energy which may be utilized is produced in the production of fissionable material, such energy may be used by the Commission, transferred to other Government agencies, or sold to public or private utilities under contracts providing for reasonable resale prices."

The potentially enormous implications of such an activity, together with others which are almost sure to be developed as the technical program unfolds, were not missed by the Congress when it framed the Atomic Energy Act. Almost certainly without parallel in the history of Government regulatory activities is a statutory provision like that of section 7 which lays down a charter for future regulation of an industry not yet in existence. Thus, section 7 provides, after having established the requirement of a Commission-issued license for the utilization of fissionable material or atomic energy, or for the manufacture, production, or export of any equipment or device utilizing the same:

"Whenever in its opinion any industrial, commercial, or other nonmilitary use of fissionable material or atomic energy has been sufficiently developed to be

of practical value, the Commission shall prepare a report to the President stating all the facts with respect to such use, the Commission's estimate of the social, political, economic, and international effects of such use and the Commission's recommendations for necessary or desirable supplemental legislation. The President shall then transmit this report to the Congress together with his recommendations. No license for any manufacture, production, export, or use shall be issued by the Commission under this section until after (1) a report with respect to such manufacture, production, export, or use has been filed with the Congress; and (2) a period of 90 days in which the Congress was in session has elapsed after the report has been so filed * * *."

Time does not permit an extensive discussion of our regulatory powers in the security field. I should simply like to point out to you that our regulations covering the criteria for determining eligibility for personnel security clearance have been printed in the Federal Register and just recently we have published in revised form a paper dealing with what we call our interim procedure for the review of cases where derogatory information appears.

Neither does time permit me to give you a detailed account of the contract appeals system which has been established, although I should like to point out to you that the Board set up to review contract disputes has since its creation in January 1947 heard 34 cases. At the present time they have a docket of 7. I think you will agree with me that in an enterprise as large as ours this seems a small number of appeals.

The field of patents is worth a separate discussion with the members of the bar. I shall, however, not attempt it today. I do commend, however, the articles written by Casper Ooms, formerly Commissioner of Patents and presently Chairman of our Patent Compensation Board, and a more recent article by Bennett Boskey, our Deputy General Counsel, which appears in the April issue of the Columbia Law Review.

Perhaps the most striking feature of the whole broad sweep of the Commission's regulatory activities is the general absence of controversies and disturbances. It is in the field of regulation—where "don't" is so often the byword—that controversy normally might be expected. The source materials regulation, as well as the production facilities regulation, both contain provisions permitting an internal appeal within the Commission from an initial decision denying a license, and yet there has not been a single appeal taken in either case. Some part of the explanation seems to lie in the manner in which AEC has, to date, gone about setting up its regulatory activities—the care which it has thus far taken to bring into its confidence at an early stage in regulatory development the persons and entities whose interest will be most vitally affected.

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59. FIRST NON-AEC NUCLEAR REACTOR TO BE BUILT AT NORTH CAROLINA STATE COLLEGE

(U. S. Atomic Energy Commission, Washington 25, D. C., for press and radio No. 316, October 29, 1950)

The first non-AEC owned and operated nuclear reactor in the United States will be built by the Consolidated University of North Carolina, using nuclear fuel loaned by the Atomic Energy Commission.

The proposed reactor, which will provide facilities for nuclear engineering research and education, will be located on the campus of the North Carolina State College, Raleigh, N. C. Present design calls for a low-power reactor having a maximum power level of 10 kilowatts, which will use enriched fuel containing not over 1 kilogram (2.2 pounds) of fissionable uranium 235.

The reactor will be housed in a special laboratory building to be erected with a fund of $200,000 that has been provided by the Burlington Mills Foundation.

Actual transfer of fissionable material required for the reactor will take place after final approval by the Atomic Energy Commission of the safety and security provisions in the completed reactor itself and the plan for its operation.

The North Carolina reactor will be a "water boiler" type reactor, similar to one that has been in operation at the Los Alamos Scientific Laboratory since 1944. The significant feature of the water-boiler design is that the uranium fuel is a solution of uranium salt in water. Such reactors are also called homogeneous reactors as contrasted to reactors in which metallic uranium fuel elements are used. At Los Alamos the water boiler has proved of great value for general research purposes.

In announcing appproval of the North Carolina reactor, AEC Chairman Gordon Dean said, "The Commission feels that the university is to be congratulated on having the foresight and initiative to make available on its own responsibility funds and technical talent to further the broad development of atomic energy in the United States.

"The proposed North Carolina State reactor will be the first reactor operated as other than a Commission-owned facility. The responsibility of construction and operation rests with the Consolidated University of North Carolina; the uses to which the reactor will be put, will be determined by the university, subject only to such control by the Commission as is required to assure that the provisions of the Atomic Energy Act of 1946 are complied with.

"It is the opinion of the Commission that the proposed reactor program will make a valuable contribution to the atomic energy program both in the training of nuclear engineers and in research."

It is expected that, in addition to the institutions of the Consolidated University of North Carolina, the project will be of material benefit to physics departments, medical schools, and other research groups throughout the entire area.

The preliminary proposal for building the North Carolina research reactor was submitted to the AEC in April 1950. On June 5, 1950, a contract was executed by the AEC under which the University of North Carolina undertook to provide, without cost to the AEC, the detailed design of the reactor with a plan for its operation and an analysis of the health and safety hazards and security considerations involved in such operations. The AEC agreed to make available to the university technical advice and consultation. The design and operating studies were made under the direction of Dr. Clifford K. Beck, chairman of the physics department, North Carolina State College.

In view of the inherent controls on this type of reactor and the low-power level at which it will be operated, the AEC's Reactor Safeguard Committee concluded that the proposed reactor can be operated safely on a university campus, provided a satisfactory plan of operation is established.

The plutonium production of the proposed reactor will total less than gram a year, an insignificant production rate in the manufacture of atomic weapons. In view of this fact and since the reactor will be useful in the conduct of research and training, the private construction, operation, and ownership of the reactor is permissible under the Atomic Energy Act.

The cost of the reactor, exclusive of the uranium fuel to which AEC will retain title, is estimated at $100,000, which will be provided by the college. Some 60 undergraduates and graduate students in nuclear engineering are enrolled at the college this semester.

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60. UNITED STATES, UNITED KINGDOM, AND CANADA MODIFY SECURITY RESTRICTIONS ON INFORMATION CONCERNING LOW-POWER RESEARCH REACTORS

(United States Atomic Energy Commission, Washington 25, D. C., for press and radio No. 320, November 24, 1950)

The Governments of the United States, the United Kingdom, and Canada have adopted a revised Declassification Guide, which will permit the publication of certain information necessary to the design, construction, and operation of specified low-power nuclear reactors used for research purposes.

The action is an outgrowth of the Fourth International Declassification Conference of February 9–12, 1950, at the British Atomic Energy Research Establishment, Harwell, England. Like the three preceding conferences, this conference was a continuation of the wartime collaboration of the three nations. It recommended revisions to the Declassification Guide used by the three nations to determine what atomic energy information held jointly may be published and what information is to remain classified.

Technical information declassifiable under the new Guide must be reviewed prior to publication, in accordance with the declassification procedures in effect in each of the three nations. Details on design, construction, and operation of the newly declassified reactors will be contained in a number of technical papers to be published after clearance through the declassification system. Values of pertinent nuclear constants of uranium, required for work in this field, will be published in a special technical report to be issued by the atomic energy agencies of the three governments.

The three governments have determined that the release of information under the revised Guide will speed the training of nuclear reactor engineers and technicians and will hasten atomic energy development in these countries, particularly for peacetime applications. It was determined that this information would not aid rival nations in the development of military applications of atomic energy. Low-power research reactors cannot be used for producing atomic weapons or power.

The United States research reactors on which design and operation information will be considered for declassification are:

(1) The world's first nuclear reactor, constructed from uranium and graphite under the west stands of the University of Chicago's Stagg Field in 1942 and subsequently dismantled;

(2) a modified version of the west stands reactor, located at the Palos Park site of the Argonne National Laboratory near Chicago;

(3) a uranium and heavy-water reactor located at the Du Page County site of the Argonne National Laboratory; and

(4) a "homogeneous" enriched uranium, light-water reactor located at the Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

British and Canadian reactors affected by the revised declassification policy are "gleep," a uranium and graphite reactor located at Harwell, England, and "zeep," a uranium and heavy-water reactor located at Chalk River, Ontario.

The information now releasable describes what must be known in order to assemble and operate a low-power research reactor. Before such a reactor can be built by a private institution, however, the permission of the Government to use the necessary fissionable materials is required. In the United States the governmental agency which controls the use of fissionable materials is the Atomic Energy Commission.

The newly declassifiable information will be useful largely in advanced courses in reactor physics. For example, it will now be possible for instructors to use specific data obtained from actual experiments, instead of discussing reactor technology in general and theoretical terms.

It is not practical to use low-power research reactors for producing atomic weapons or power.

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61. PROPOSAL FOR ATOMIC POWER STUDY

WASHINGTON, D. C., *December 11, 1950.*

ATOMIC ENERGY COMMISSION,
1901 Constitution Avenue NW., Washington, D. C.
(Attention: Gordon Dean, Chairman.)

GENTLEMEN: The Detroit Edison Co., the Dow Chemical Co., and their associates are desirous of aiding in the advance toward economical industrial utilization of nuclear power and reactions. The realization of this could provide this country with vastly increased amounts of nuclear material for both war and peace. To this end, the above group proposes that they undertake an economic design survey of possible stationary nuclear reactors producing usable power with the hope of shortening the period of time otherwise required for this development.

It is hoped that the above project will ultimately develop a type of reactor which will permit economical production of power, fissionable material, and fresh fission products on a very large scale and with optimum raw-material utilization.

The specific objectives are:

1. To compare possible nuclear reactors which might realize the following objectives:

a. Produce more fissionable material.

b. Separate fresh fission products in packaged form.

c. Facilitate economical production of power with minimum use of scarce materials and consider the use of partly depleted uranium or thorium for make-up fuel.

2. To choose and describe a promising example which will be advocated for further study and tests and eventual design.

The private facilities required and available are:

The facilities for conducting this research will include the engineering staffs and research facilities of the Detroit Edison Co. and the Dow Chemical Co., and the services, as necessary, of consultants from companies in allied fields.

The cost of the above phase of this study will be borne by the Detroit Edison Co. and the Dow Chemical Co.

In order to carry out the proposed program, the following action by the United States Atomic Energy Commission is required:

1. Personnel clearance for this project for:
a. The Dow Chemical Co.
b. The Detroit Edison Co.
c. The Babcock & Wilcox Co.
d. Nuclear Development Associates, Inc.
2. Access to the classified literature for the above personnel.
3. Some access to qualified AEC personnel under the complete control of the Director of the Reactor Division.
4. Some simple, mutually agreeable, contractual arrangement.

No publicity is desired on this project except as the United States Atomic Energy Commission may determine.

Respectfully submitted.

[s] J. W. Parker
JAMES PARKER, *President*,
THE DETROIT EDISON CO.

[s] Mark E. Putnam
MARK E. PUTNAM, *Vice President*,
THE DOW CHEMICAL CO.

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62. AEC DECISION TO INSTITUTE INDUSTRIAL PARTICIPATION STUDIES

UNITED STATES ATOMIC ENERGY COMMISSION,
Washington 25, D. C., January 25, 1951.

Hon. BRIEN MCMAHON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR SENATOR MCMAHON: This is to report to the Joint Committee a recent decision by the Commission to explore the possibility of bringing interested groups in American industry into the reactor development program on a basis different from that which has been our practice. The first step in carrying out this decision is illustrated by the enclosure, a proposed statement to the press for release in the near future.

As this document indicates, the Commission has had proposals from two industrial groups expressing their willingness to bring their technical resources into the atomic energy program at their own expense. Both groups are interested in the long range prospect of producing electric power from nuclear energy. Both groups desire a substantial measure of independence and responsibility in carrying out their proposals and both have expressed an interest in financing at least the first step proposed in each case, a survey of the present state of reactor technology in this field.

One proposal is from the Monsanto Chemical Co. of St. Louis, Mo., representing an undisclosed group of industrial organizations. The other is from the Detroit Edison Co. of Detroit, Mich., together with the Dow Chemical Co. of Midland, Mich.

The Monsanto proposal suggests that "American industry design, construct, and operate one or more atomic power plants with its own capital" and that "power and plutonium would under such a plan be produced in the same plant from Government-owned uranium." In subsequent discussions, Dr. C. A. Thomas, of the Monsanto Co. proposed that the creation of such a reactor would probably involve three steps, i. e., (1) a study of the Commission's reactor development program, (2) development and design work, and (3) the construction and operation of the reactor. It was stated that step (1) would be supported by a group of industrial firms if the Commission could give assurance of its support of subsequent work.

The Detroit Edison and Dow Chemical Cos. in a more limited proposal suggest that they and their associates aid in the development and use of reactors for industrial purposes by undertaking at their own expense a survey of the economic and technical feasibility of building and operating reactors for the production of fissionable materials, fission products, and power with the minimum use of scarce

materials; the Commission has construed this as substantially equivalent to step (1) of the Monsanto proposal.

The Commission has now written to these groups indicating the extent of its interest and inviting each to describe the arrangements under which it would be willing to proceed.

The Commission is interested in exploring these proposals for several reasons. They appear to offer an opportunity for bringing new technical and management resources into the atomic-energy program. They also are oriented toward important Commission objectives—the production of plutonium and other important materials, together with power, in a reactor. They may lead to arrangements where, because initiative is with industry, additional incentives for rapid and aggressive technical and business development will exist.

You will note that the Commission intends to explore only the study phase and has stated that any commitment it may make at this time will not go beyond providing to properly qualified and cleared persons existing information and a reasonable share of the time of Commission personnel.

One of our primary purposes in making a public statement about these proposals is to give other interested and qualified industrial groups a similar opportunity to discuss their interest with us.

As the statement to the press indicates, groups submitting proposals must set forth a well-defined statement of objectives, must be financially responsible and equipped with a staff of adequate qualifications and size, and must undertake to submit a report including detailed findings and recommendations at the conclusion of any study. It is stipulated that these reports may be disseminated at the discretion of the Commission to the extent consistent with security.

Sincerely yours,

UNITED STATES ATOMIC ENERGY COMMISSION,
SUMNER T. PIKE, *Acting Chairman.*

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63. STATEMENT BY THE UNITED STATES ATOMIC ENERGY COMMISSION ON MEANS OF WIDENING INDUSTRIAL PARTICIPATION IN ATOMIC ENERGY DEVELOPMENT

(U. S. Atomic Energy Commission, Washington 25, D. C. No. 341, January 28, 1951)

In recent months the Commission has received proposals from two industrial groups expressing willingness to bring their technical resources into the atomic energy program under somewhat different arrangements, in which a large share of initiative and responsibility would rest with the industrial group.

Both of these groups would study the feasibility of developing and operating nuclear reactors for the production of plutonium and with the ultimate goal of producing electric power. One proposal was presented by Mr. C. A. Thomas, executive vice president of the Monsanto Chemical Co.; the other by Mr. J. W. Parker of the Detroit Edison Co. and Mr. M. E. Putnam of the Dow Chemical Co.

These proposals appear to offer not only an opportunity for bringing new technical and management resources into the atomic energy program; they also are oriented toward important Atomic Energy Commission objectives—the production of plutonium and other important materials, together with power, in a reactor; and they may ultimately lead to arrangements where, because initiative is with industry, additional incentives for rapid and aggressive technical and business development will exist.

The Commission has discussed these proposals with the men whose vision created them, and has suggested conditions under which it would be willing to go forward with the first step involved in each proposal—a study of its reactor development program by qualified technical groups from the industrial concerns involved. These groups are visualized as consisting of 10 to 15 individuals.

The following general policy guided consideration of these proposals:

The Commission will undertake cooperative activities with industrial concerns or groups of concerns to explore possibilities for their participation—on their own initiative, using their own resources—in development of applications of atomic energy for power purposes in such manner and extent as to insure: (1) maximum attention to the atomic energy production program in all its phases; (2) special effort being placed on those matters that will be productive in the relatively near future (1 to 3 years); (3) the application of the best available brains to all the important problems of the Commission.

To guide the General Manager and staff in considering further proposals in this field from industrial concerns or groups, the Commission has specified that those submitting such proposals should put forth a well-defined set of objectives for their proposed study, should be financially responsible and equipped with a staff of adequate qualifications and size, and should undertake to submit a report including detailed findings and recommendations at the conclusion of the study. These reports would be disseminated at the discretion of the Commission to the extent consistent with security.

The Commission has also directed that no commitment be made at this time to continue beyond the study phase. If satisfactory arrangements can be made for proceeding with these studies, the Commission will make available to properly qualified and cleared persons existing information and a reasonable share of the time of Commission personnel.

SAMPLE AGREEMENT FOR INDUSTRIAL STUDY PROGRAM

AGREEMENT BETWEEN _____ AND THE UNITED STATES ATOMIC ENERGY COMMISSION

General objectives

1. The _____ referred to hereafter in this letter as the company (companies), desires (desire) to undertake (jointly) a study to determine the desirability of proceeding with the engineering design and construction of a power and materials producing reactor.

2. The Atomic Energy Commission is willing, in the interest of forwarding the atomic energy program, to assist the company (companies) in carrying out this study by making available pertinent information and, for consultation purposes, a reasonable share of the time of its personnel and that of its contractors.

3. One of the major objectives of the Commission's reactor program is the creation of a large-scale reactor to produce fissionable materials and power as joint products; the Commission believes that this study is compatible with its objective.

Terms of agreement

1. *Purpose and scope.*—The company (companies) will make a survey and study of the Commission's reactor development activities:

(*a*) To determine the engineering feasibility of their designing, constructing, and operating a materials and power producing reactor.

(*b*) To examine the economic and technical aspects of building this reactor in the next few years.

(*c*) To determine the research and development work needed, if any, before such a reactor project can be undertaken.

(*d*) To offer recommendations in a report to the Commission concerning such a reactor project and industry's role in undertaking and carrying it out.

The work of the company (companies) under this agreement will be limited to this survey and study. The Commission's responsibilities in connection with this undertaking will be limited to the terms of this letter.

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2. *Assistance of others.*—For the purposes of this study the company (companies) may employ, with the approval of the Commission, the services of other organizations and persons.

3. *Term.*—The study will begin upon acceptance of the terms of this letter and will be completed as soon thereafter as the work can be accomplished. In any case the study shall be completed and reported to the Commission no later than 1 year after the date of acceptance.

4. *Costs.*—All costs of carrying out this study will be borne by the company (companies) with the exception of costs to the Commission and its contractors incidental to making information and consultation services available.

5. *Reporting.*—Upon completion of the study the company (companies) will submit a report to the Commission, including its (their) findings and recommendations. This report will be distributed as the Commission sees fit.

6. *Security.*—The Commission will grant security clearance, after completion of the necessary background investigations and reports, for a sufficient number of people in the employ of the company (companies) to permit the study to be carried out. The total number will be kept to a minimum. It is understood that no more than _____ such clearances, in addition to those already granted in connection with other atomic energy activities of the company's (companies')

employees, will be required. Additional agreements relating to security are contained in appendix A.

7. *Information.*—The Commission will make available at its own expense all the reports and other data pertinent to this study. The company (companies) will be given access to the Commission's files in order to determine what material is needed.

8. *Consultation.*—The Commission will arrange for representatives of the company (companies) to visit its laboratories and plants, and those of its contractors, for the purpose of observing and discussing matters pertinent to this study. These visits and discussions will be planned so as to interfere as little as possible with Commission work already under way. In this connection, it is understood that no more than _____ people, including technical personnel, will have access to Commission installations and consultants.

9. *Patents.*—In view of the preferred position in terms of access to information and know-how developed at public expense, which is not generally available to others but which the company (companies) will necessarily obtain in the conduct of this study, the Commission deems it important to provide that all inventions and discoveries made in the course of the work covered by this agreement be the property of the Government. Our standard patent article to accomplish this purpose is included in appendix A and will be considered to be a part of this agreement.

10. *General.*—A number of other matters on which agreement is necessary, including standard clauses required by law or by Commission policy, are annexed hereto as appendix A, which shall be deemed a part of our agreement. It is expected that the company (companies) will consult with the Commission prior to the release to the public of statements relating to the work under this agreement.

11. *Administration.*—The undersigned, or his designee, will have responsibility for the administration of this agreement on behalf of the Commission. Unless the Commission is notified to the contrary, _____ will be regarded by the Commission as having responsibility for administration of the agreement on behalf of the company (companies).

LAWRENCE R. HAFSTAD,
Director of Reactor Development.

APPENDIX A

1. Patents

(*a*) Whenever any invention or discovery is made or conceived by the company (companies), its (their) employees, or its (their) associates, in the course of any of the company's (companies') activities under this letter agreement, the company (companies) shall furnish the Commission with complete information thereon; and the Commission shall have the sole power to determine whether or not and where a patent application shall be filed, and to determine the disposition of the title to and rights under any application or patent that may result. The judgment of the Commission on these matters shall be accepted as final; and the company (companies), for itself (themselves), its (their) employees and its (their) associates agree that the inventor or inventors will execute all documents and do all things necessary or proper to carry out the judgment of the Commission.

(*b*) No claim for pecuniary award or compensation under the provisions of the Atomic Energy Act of 1946 shall be asserted by the company (companies), its (their) employees or its (their) associates with respect to any invention or discovery made or conceived in the course of any of the activities of the company (companies) under this letter agreement.

(*c*) Except as otherwise authorized in writing by the Commission, the company (companies) will obtain patent agreements to effectuate the purposes of paragraphs (*a*) and (*b*) above, from all persons who perform any part of the work under this letter agreement, except such clerical and manual labor personnel as will not have access to technical data.

2. Security

(*a*) In the performance of the work under this agreement the company (companies) shall, in accordance with the Commission's security regulations and requirements, be responsible for safeguarding restricted data and other classified matter and protecting against sabotage, espionage, and theft, the classified documents, materials, equipment, processes, and similar things, as well as such other material of high intrinsic or strategic value as may be in the company's (com-

panies') possession in connection with performance of the work under this agreement.

(*b*) The company (companies) agrees (agree) to conform to present security regulations and requirements of the Commission.

(*c*) The term "restricted data," as used in this agreement, means all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the Commission from time to time determines may be published without adversely affecting the common defense and security.

(*d*) Except as the Commission may authorize, in accordance with the Atomic Energy Act of 1946, the company (companies) shall not permit any individual to have access to restricted data until the Federal Bureau of Investigation shall have made an investigation and report to the Commission on the character, associations, and loyalty of such individual and the Commission shall have determined that permitting such person to have access to restricted data will not endanger the common defense or security.

(*e*) It is understood that disclosures of information relating to the work under this agreement to any person not entitled to receive it, or failure to safeguard any restricted data or any top secret, secret, confidential, or restricted matter or matter classified "official use only," that may come to the company's (companies') or any person under the company's (companies') control in connection with the work under this agreement, may subject the company (companies), its (their) agents, employees and associates, to criminal liability under the laws of the United States. (See the Atomic Energy Act, of 1946, 60 Stat. 755, as amended, title 42, U. S. C. sec. 1601 et seq. *See also* title 18, U. S. C. sec. 791, 797, and Executive Order 10104 of Feb. 1, 1950, 15 F. R. 597).

(*f*) Except as otherwise authorized in writing by the Commission, the company (companies) shall insert provisions similar to the foregoing in all agreements made in carrying out the work under this agreement.

3. Discrimination

The company (companies), in performing the work under this agreement, shall not discriminate against any employee or applicant for employment because of race, creed, color, or national origin. The company (companies) shall cause provisions similar to the foregoing to be inserted in all agreements made in carrying out the work under this agreement.

4. Officials not to benefit

No member or delegate to Congress or resident commissioner shall be admitted to any share or part of this agreement or to any benefit that may arise therefrom, but this provision shall not be construed to pertain to this agreement if made with the company (companies) for its (their) general benefit.

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64. ENGINEERING PROBLEMS IN NUCLEAR POWER PLANT DEVELOPMENT

Address of D. Cochran, Engineering Division, Knolls Atomic Power Laboratory, before the metropolitan section, American Society of Mechanical Engineers in New York City, February 20, 1951

This will be a short and very general, rather than specific, discussion indicating some interesting and unique engineering problems related to the development of nuclear power plants.

What I say may leave you with the impression that we are hopelessly bogged down in a morass of insoluble difficulties. Such is not the case, and I wish to say so emphatically now at the outset. We have a number of difficult problems but we are working on many ideas which should yield acceptable solutions to these problems. It is certain, however, that although some of the solutions are acceptable, they will not be the best possible solutions, and so we look forward to a continuing development and improvement as we accumulate experience in the design and operation of nuclear power plants.

The method of generating useful electrical power from nuclear energy being worked on now is to circulate a cooling fluid through the nuclear reactor to carry away its heat. The coolant leaves at high temperature and passes through heat exchangers where the heat is transferred to water, making steam. The steam drives turbine-electric generators.

Such nuclear power plants have many characteristics in common with other types of power plants, such as central station steam plants, aircraft gas turbines, and diesel-electric power plants. You are familiar with characteristics of these plants that give rise to engineering problems. The necessity for high temperatures in efficient power plants is a primary factor, leading to many difficult engineering problems. In some power plants, high pressures in fluids are required, and these lead to engineering development and design problems. In all power plants, the factor of cost is important, giving rise to many engineering problems. Nuclear power plants, however, contain other unusual factors causing new and unusual engineering problems.

Perhaps the most important of these factors is the presence of very intense neutron and gamma radiation emanating from the nuclear fuel as it is consumed in the reactor core.

This radiation will break up chemical compounds, displace atoms in crystal lattice structure, and in general bring about quite important changes in the submicroscopic structure of many materials within the reactor.

It is necessary to shield against this radiation for protection of personnel. This means that the reactor must be surrounded by a heavy and complicated shielding structure.

In addition to the nuclear fuel which is consumed in the reactor core, the fluid circulating through the reactor core to carry away heat may, in certain types of reactor power plants, become quite radioactive. The radioactivity of the coolant makes necessary a degree of leak tightness in the circulating system which is far beyond the requirements of ordinary power plants and which gives rise to a number of new and difficult engineering problems. The radiation from the reactor core and the reactor coolant is not something that can be turned off when the reactor power is shut down. This radioactivity persists for a long time and makes it very difficult to carry on maintenance work, replacements, or adjustments within the radioactive zone of the power plant. The inaccessibility, for maintenance, of a large portion of a nuclear power plant is a new condition which must be met.

Another unusual factor in nuclear power plant design is that a number of exotic and unusual materials are employed in the reactor structure. The need for these comes from the requirement that structural materials, moderating materials, and heat transfer fluids have very particular nuclear properties. They must not absorb too many neutrons and must not be damaged by the radiation. So we find that metallic elements hitherto relatively rare and about which little is known from the standpoint of engineering properties, are now being employed in reactors as structural materials. The technology of these new materials is developing rapidly but still remains one of the important, new, scientific, and engineering problems in nuclear power plant development.

A further aspect of the material question is the necessity for a high degree of purity in reactor structural materials and coolants. Again, because of the high absorption of neutrons by certain impurities in metallic structural materials, or because of the corrosive or contaminating qualities of impurities in heat transfer fluids, new engineering problems are encountered in attaining the required degree of purity.

Still another unusual factor in nuclear power plants is the presence of fission products, the radioactive fragments of fissioned fuel atoms. They give rise to engineering problems in handling the fuel after it has been partially consumed, and in separating and salvaging the unconsumed fuel. They constitute a very dangerous waste material which must be disposed of.

All these factors have a bearing in one way or another on the design and operation of the nuclear power plant. The following is a discussion of some of the principal elements of the plant, with an indication of some of the engineering problems which concern us.

First, consider the nuclear fuel. Uranium and plutonium are themselves difficult engineering materials from the standpoint of their fabrication and structural capabilities. The fuel in a nuclear reactor must be distributed in such a way as to present a great deal of surface for heat transfer to the reactor cooling fluid. The heat generated in nuclear fuel of a high powered reactor is very intense indeed, being, for example, many times more intense than the heat generated due to I^2R loss in the copper conductors of an electric motor. So, for a high powered nuclear reactor, the fuel must be finely divided and distributed in order to permit extraction of its heat.

Nuclear fuel materials would be corroded and eroded by most reactor coolants if they were in direct contact. Further, as the fuel is consumed, radioactive fission products are formed. It is generally desirable to contain these

fission products, and it is necessary to protect the fuel from the coolant. So the fuel must be packaged or jacketed in such a way as to contain it and yet provide for good heat transfer to the coolant.

The behavior of a nuclear reactor is very strongly affected by the positioning of the nuclear fuel throughout the reactor structure. It is necessary to devise a fuel structure which will enable accurate and stable positioning of the fuel, regardless of changes in pressures, temperatures, and the flow of coolant, vibration, and, in the case of mobile reactors, shock, and acceleration.

The reactor structure itself must satisfy several rather severe requirements. Since the metallic structural materials now generally in use, such as stainless steel and aluminum, absorb neutrons, it is necessary to provide extra fuel to compensate for the loss of neutrons in the structural material. In order to minimize this extra fuel investment, a very minimum of structural material must be employed in the reactor core structure. This core structure serves the function of positioning the fuel elements and providing the channels through which the reactor coolant flows. It must be strong, stable and durable under high temperature and radiation. After the reactor has been run, the reactor core structure, because of the absorption of neutrons, becomes radioactive in itself, so that even though the nuclear fuel is removed and the coolant drained away, the core structure is still so radioactive that it is not possible to carry out any repairs or adjustments except those very limited operations which can be done by means of remotely operated tools. No procedure of cutting and trying reactor parts under development can be used because of this radioactivity. In other engineering developments, structural parts which fail can be replaced, usually without such difficulty as to make the entire machine useless. In the case of the nuclear reactors, sufficient analytical design work and simulated testing of reactor components must be done in advance that when the reactor itself is finally assembled and operated, the greatest degree of certainty of successful functioning of the parts will already have been attained.

The reactor core must be capable of withstanding rigorous service. It is bombarded by a tremendous flux of neutrons and gamma radiation. It operates at high temperatures. It must be capable of withstanding severe thermal shocks which come about during load changes. It must survive the vibrations and mechanical shocks resulting from the dynamic forces of the reactor coolant and, if it is an aircraft or shipboard propulsion unit, from the shocks and accelerations experienced by mobile power plants.

Moderating materials are a part of the reactor structure to slow down the neutrons so that they may be more readily captured to cause new fissions. The moderating material in a reactor undergoes the same severe service as does the rest of the reactor structure and must have the same resistance to damage.

The reactor coolant ideally must possess a number of properties which are not uncommon in heat transfer fluids but which are not all found in a single fluid. First, the coolant must not absorb too many neutrons because the neutrons lost to the coolant must be compensated for by extra fuel investment. The coolant must be stable under the tremendous bombardment of radioactivity in the reactor core. It must be stable at high temperatures. For good heat transfer, it should have high thermal conductivity, high specific heat, and, for low pumping power, low viscosity.

It is necessary that the coolant, if a liquid, does not boil and vaporize in the reactor core (contrary to the scheme depicted in a recent issue of Life magazine). Therefore, a reactor coolant liquid having low vapor pressure is desirable.

The reactor coolant must be relatively noncorrosive and nonerosive, since many of the reactor parts in contact with it are not replaceable. It should be chemically inert and, finally, it ought to be cheap and plentiful.

As you can see, this is a long list of requirements. No single substance has been found which meets all of them. In general, when considering reactor coolants, it is not possible to compromise the nuclear requirements, so that any compromises involved in the selection are engineering compromises. Thus, for example, where water is chosen as the coolant for a high temperature power-producing reactor, it is necessary to tackle the engineering matter of containing the water in the reactor core at high enough pressure to prevent its vaporization in the reactor.

Some liquid metals are attractive as reactor coolants in that they have excellent heat transfer properties and much lower vapor pressures than water but possess the difficulty that they are very active chemically, and, further, that they become extremely radioactive in the course of their circulation through the reactor core. Hence, it is necessary to provide shielding for the external heat

transfer system, and this adds to the weight, size, and complication of the plant, as well as making a greater portion of it relatively inaccessible for maintenance.

Some gases have the advantage of not becoming radioactive, and hence are more convenient to handle outside the reactor, but all gases are relatively poor heat transfer fluids as compared with water and liquid metals. To be at all competitive, they must be operated at extremely high pressures, and they require great amounts of power to pump at velocities necessary for reasonably good heat transfer. At the present time, gas reactor coolants are not strong contenders in the selection for high power nuclear reactors.

The nuclear reactor is controlled by moving elements within the reactor structure. This motion must be extremely precise and reliable. Means must be devised for actuating the control elements and indicating their position. They must not stick nor move erratically. There must be no leakage of reactor coolant at the points where motion is transmitted into the reactor container.

As has been indicated earlier, the reactor and such parts of the heat transfer system as contain radioactive coolant must be shielded. The first requirement of shielding materials is that they absorb radiation adequately for protecting the personnel who operate and are near the power plant. In addition, the shield ought to be light in weight, compact, and cheap. It is particularly important in the case of mobile reactors that the shielding be as compact and light as possible, for it turns out that the shield itself probably weighs more than all the rest of the power plant, in most instances. The shield must be mechanically stable and capable of withstanding the rigors of normal operation. It should not be damaged by the irradiation which it experiences. There must be provision for removing the heat generated in it by the absorption of nuclear radiation.

Much work is being done on shielding. For stationary power plants—where there is plenty of space and where size and weight are not a primary consideration—rather ordinary materials, such as concrete, iron, and water, could be used for shielding. In mobile reactors, more exotic materials are being investigated, as is the case with the reactor structure, it is developing that some of those materials have the best properties for stopping radiation do not have good structural properties, so the technology of their preparation and utilization in reactor-shielding structures is a matter of much concern to nuclear engineers.

The external heat-transfer system in a nuclear power plant is the equipment in which heat from the reactor coolant is used to make steam which will drive a steam turbine. The heat exchangers, the piping between them and the reactor, together with the reactor container itself, constitute an envelope which must contain the radioactive reactor coolant with a degree of leaktightness and reliability that is very unusual in large systems according to ordinary engineering standards. It is true that in the case of certain reactor coolants, the leakage of a very few cubic centimeters (about a jigger to those who are more familiar with this unit of liquid measure) may release enough radioactivity to the surroundings to make the power plant uninhabitable. Many components of an ordinary steam power plant are subject to copious leaks as compared with this standard. Valve packing glands, pump shaft seals, pipe flanges, and turbine shaft seals, all leak to the extent that it is necessary to add make-up of many gallons of water per day to the boiler. The reactor coolant system simply must not leak at all.

The heat exchangers, piping, reactor container, and other system components which make up this necessarily impervious envelope to contain the coolant, generally may be of a heavy, rugged structure wherein good engineering practice will insure great integrity. However, it is necessary to transmit through this envelope certain motions, pressures, or considerable amounts of energy, and the points at which these pass through the envelope constitute points of weakness. A great amount of effort is being applied to achieving the necessary soundness and reliability at these points.

For example, as has been mentioned, the reactor is controlled by moving control elements within the reactor structure. These motions may be accomplished by transmitting the motion from outside the reactor container through rotating or translating shaft seals or through bellows. Where the reactor coolant pressure is measured, a soft spot in the envelope must exist to transmit pressure fluctuations from within the container to the outside. The very thin diaphragms or bellows required for this pressure indication, again, are sensitive or vulnerable spots in the containing envelope. The pumps which circulate the reactor coolant are points at which rather large amounts of energy must be transmitted from outside through the containing envelope and imparted to the reactor coolant.

This involves shaft seals or thin diaphragms through which electromagnetic forces may be transmitted, and these are serious points of vulnerability in the system.

Many of the instruments in a nuclear power plant are similar to those in an ordinary power plant. However, the aspects of leaktightness, reliability, and inaccessibility for maintenance, which have been mentioned, give rise to more exacting requirements in these instrument applications. Devices for detecting radiation, pressure, temperature, fluid flow, and liquid level all must operate in the presence of very great radioactivity and at high temperatures without maintenance or adjustment. Considerable effort is now being directed toward their development.

As a nuclear power plant operates, it is necessary from time to time to remove spent fuel elements and to insert, new, fresh fuel elements. This must be accomplished without jeopardizing the integrity of the system containing the reactor coolant. The radioactivity of the reactor itself and of the spent fuel elements which are removed make necessary that the entire operation of unloading and reloading a power reactor be accomplished by remotely controlled mechanisms. The operations involved require considerable precision, and clever means for accomplishing the somewhat complicated manipulations are being developed. Elaborate optical systems, telemetering devices, and servo-mechanisms are employed to carry out the reloading procedure remotely.

After the fuel has been removed from the reactor, usually only part of it has been consumed, and it is necessary that the fuel elements be chemically and matallurgically processed to salvage the unconsumed fuel and prepare it for reuse in the reactor. After this the radioactive fission products must be disposed of. In the present state of development of nuclear reactors, the rate of generating fission products having very long-lived radioactivity is such that the fission products may simply by stored in isolated areas. However, if the time comes when there is widespread use of nuclear power, the disposal of these fission products will be a very real and serious problem. While it is not Commission practice to dispose of radioactive wastes by distributing them widely in the ocean, some arithmetic has been done for illustrative purposes which indicates that if any considerable fraction of the electrical power used in the United States were to come from nuclear reactors the rate of producing fission products would be such as to preclude that method of disposal. Even though the ocean is vast, it would become saturated at some locations with fission products to a degree that would not be tolerable.

Finally, an area in which there are interesting engineering problems is the laboratory testing of radioactive substances. Nuclear engineers are concerned with the behavior of structural materials, coolants, insulators, and lubricants under irradiation, and so tests are being made of the engineering properties of these materials after they have been irradiated. Most materials when irradiated become themselves so radioactive that they cannot be handled directly. So we are developing a new technology of laboratory testing using remotely controlled testing devices and handling devices. Quite a bit of publicity has been given to this aspect of the nuclear energy developments, and much ingenuity is being applied to the development of clever gadgets for this work.

As you can see from all that has been said, I am able to indicate here only the general nature of some of the engineering problems which confront engineers in the development of useful nuclear power. I cannot give a more specific discussion of these problems because of security restrictions. We have good solutions in hand for some of them. For others, we are working on solutions which are not ideal but are as good as could be hoped for at this early stage. In general, some sort of acceptable solution is being pursued on all of the problems, and we are optimistic as to the outcome.

However, if we are to make the best possible progress in the development of nuclear power, we must enlist the help of many engineers and manufacturing concerns in addition to those laboratories and companies directly responsible for the reactor development projects. It has been said many times that there must be a widespread involvement of American industry in nuclear developments if the whole enterprise is to succeed, and I can tell you from my first-hand experience that this is indeed the case. We are doing everything we can to get help from outside our project on these problems where specialized experience of others may bring a better solution.

Many of the components in a nuclear power plant are found in other plants, such as pumps, instruments, heat exchangers, pressure vessels, etc. The experience of industry in the development of these is all applicable to the corresponding parts of our plant. However, the difference in our work lies in the

extreme degree of perfection required of these components in nuclear power plants. This perfection, of course, is necessary because of the very serious consequences of failure in such a plant. I believe this is the major difference between nuclear power plants and other power plants. Perfection is difficult to attain, but it must be attained in some parts of a nuclear power plant if the plant is to operate satisfactorily.

I wish I could tell you more about how we stand today, but I cannot, so I will close by saying that we have a great enthusiasm for the job, and that many capable people are putting their best efforts into it. As President Truman said in presenting his recent budget request to Congress, in the field of useful nuclear power "good progress is being made."

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65. UNITED STATES AIR FORCE AND ATOMIC ENERGY COMMISSION TERMINATE ONE PHASE OF NUCLEAR POWER FOR AIRCRAFT STUDY

[U. S. Atomic Commission, Washington, D. C., No. 345, February 22, 1951]

The United States Air Force and the United States Atomic Energy Commission announced today that the NEPA Division of the Fairchild Engine & Airplane Corp. has completed its contract for studies in the field of the development of a nuclear-powered aircraft.

The NEPA Division has carried out experimental work at Oak Ridge, Tenn., for over 4 years as a basis for a number of special reports required by the Air Force, the Atomic Energy Commission, and the Navy Bureau of Aeronautics. The facilities and equipment used in this work will be utilized in other programs and temporary buildings will be dismantled. The NEPA program will be terminated as of April 30.

Other projects being supported by AEC and the Air Force in the field of nuclear-powered flight will be continued. A group of leading aviation engine manufacturing companies has participated in the research under contracts with the Fairchild Engine & Airplane Corp. The following companies are in this group: Allison Division, General Motors Corp.; Continental Aviation & Engine Corp.; Fredric Flader, Inc.; General Electric Co.; Lycoming Division, AVCO Manufacturing Corp.; Northrop Aircraft, Inc.; United Aircraft Corp.; Westinghouse Electric Corp.; Wright Aeronautical Corp. In addition, several industrial research laboratories and distinguished scientific consultants were associated with Firchild in the work at Oak Ridge.

In announcing the completion of one phase of the nuclear-powered flight program the Air Force highly commended the pioneering research and accomplishments of Fairchild and the associated aviation engine manufacturing companies.

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66. ATOMIC ENERGY COMMISSION AUTHORIZES CONTRACT NEGOTIATIONS FOR AIRCRAFT NUCLEAR REACTOR WITH GENERAL ELECTRIC GAS TURBINE DIVISION

[U. S. Atomic Energy Commission, Washington, D. C., No. 358, March 24, 1951]

The Atomic Energy Commission has authorized negotiation of a contract with the Aircraft Gas Turbine Divisions of General Electric Co., Cincinnati, Ohio, for the further development of a nuclear reactor for aircraft. The nuclear reactor development will parallel the development of associated propulsion devices for which the Air Force has previously announced contract negotiations with General Electric.

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67. ATOMIC ENERGY COMMISSION TO DISCUSS BENDIX AVIATION CORP. PROPOSAL FOR FEASIBILITY STUDY OF ISOTOPE REACTOR

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 365, April 4, 1951)

The Atomic Energy Commission and the Bendix Aviation Corp., Detroit, have started discussions of a Bendix proposal to undertake a privately financed feasibility study of a nuclear reactor to produce radioisotopes on a commercial basis. The Commission's action is in line with its previously announced policy

of encouraging wider industrial participation in reactor developmental phases of the national atomic energy program.

Under this policy the Commission is undertaking cooperative activities with industrial concerns to explore the possibilities for their participation—on their own initiative, using their own resources—in development of commercial applications of atomic energy. The Commission's cooperation in such investigations will be extended so as to insure:

1. Maximum attention to the atomic energy production program in all its phases.

2. Special effort on those matters that will be productive in the relatively near future (1 to 3 years).

3. The application of the best available brains to all the important problems in the atomic energy program.

The Commission now has before it proposals from industrial groups or firms for studying the practicality of designing and building materials-power producing reactors and for studying the developing industrial uses of radioactive fission products. In each case the firm has suggested that it carry out the study phase with its own personnel and funds, the Commission being expected to make available pertinent information and a reasonable share of the time of its employees, and those of its contractors, for consultation.

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68. ATOMIC ENERGY COMMISSION WILL CONSIDER MAXIMUM OF FOUR INDUSTRIAL REACTOR STUDIES

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 373, May 16, 1951)

The Atomic Energy Commission today announced negotiations are nearing completion with four groups of business and industrial firms under a previously announced program for expanded participation in reactor development projects and that no additional groups can be admitted at this time.

The four proposals provide for special studies of the practicability of business and industry building and operating reactors for the production of fissionable materials and power. They were submitted by: The Monsanto Chemical Co., St. Louis., and its associate, the Union Electric Co. of Missouri, St. Louis; the Detroit Edison Co. of Detroit and the Dow Chemical Co. of Midland, Mich.; the Commonwealth Edison Co. and the Public Service Co. of Northern Illinois, of Chicago; the Pacific Gas & Electric Co. and the Bechtel Corp. of San Francisco.

Agreements have already been signed with the Dow Chemical-Detroit Edison group and with Commonwealth Edison-Public Service of Northern Illinois group. The Pacific Gas & Electric-Bechtel group has indicated its acceptance of the agreement. Negotiations are continuing with the Monsanto Chemical Co., and the Commission expects early closing of the agreement with it.

Consideration by the Commission of additional proposals will be postponed for the time being, since it is felt that four study projects is the maximum that can be carried on simultaneously in view of the demands that will be placed on technical personnel of the AEC and its laboratories and contractors. The two laboratories principally concerned are the Argonne National Laboratory at Chicago and the Oak Ridge National Laboratory at Oak Ridge, Tenn., both of which have heavy development programs of high importance to the national defense.

These study projects do not include a special proposal by the Bendix Aviation Corp. of Detroit, for study of a reactor for the production of isotopes to be built with private funds. The Bendix proposal is now in a preliminary discussion stage.

In general, the terms of the agreements executed with the Dow Chemical-Detroit Edison group and with the Commonwealth Edison-Public Service of Northern Illinois group provide that the companies will make a survey and study of the Commission's reactor development activities—

(1) To determine the engineering feasibility of their designing, constructing, and operating a materials and power producing reactor.

(2) To examine the economic and technical aspects of building this reactor in the next few years.

(3) To determine the research and development work needed, if any, before such a reactor project can be undertaken.

(4) To offer recommendation in a report to the Commission concerning such a reactor project and industry's role in undertaking and carrying it out.

The maximum time permitted for the study is 12 months after signing of the letter agreement.

All costs will be borne by the companies with the exception of costs to AEC and its contractors incidental to making information and consultation services available. The distribution of the final report submitted on the project will be determined by AEC.

AEC will grant security clearances after an FBI background investigation for a sufficient number of company personnel to carry out the study. The number of cleared company personnel who will have access to reactor installations and consultants will be limited to 15.

All inventions and discoveries made in the course of the work will be the property of the Government.

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69. THE UNITED STATES ATOMIC ENERGY PROGRAM, 1951

Remarks by Gordon Dean, Chairman, United States Atomic Energy Commission, Before the New York State Chamber of Commerce New York City, June 7, 1951

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The most distinguishing characteristic of the next most widely mentioned product of atomic energy—atomic power—is that it is not yet on the market, and I, for one, am extremely hesitant to say just when it will be. There are several reasons for this. In the first place, there are technical difficulties which stand in the way of building atomic power plants at costs that will make them economical to operate . In our present state of knowledge, we could undoubtedly build an atomic power plant right now, but there is no chance in the world that it could produce power at anything approaching the relative low cost of power produced from coal or by hydroelectric means. We will, as a matter of fact, sometime this year, put a reactor in operation at our Idaho testing station that has been designed to produce, as an experiment, something over 100 kilowatts of power, but it will not be the kind of plant that will be needed to produce power commercially. It will be, instead, primarily a research reactor, and its main purpose will be to test the process we call bleeding—which is an attempt to operate a reactor in such a way that it will produce more fissionable material than it consumes.

Another important reason why commercial atomic power isn't right around the corner is that the need for a new source of commercial power in this country—with its vast deposits of coal and oil and its hydroelectric systems—is not as great at the moment as some of the other needs that the products of atomic energy can help meet. By this I mean that at the present time the needs of national defense are paramount, and in this kind of a setting, I think, it is only natural that even our quest of atomic power is directed down military channels. We are, therefore, concentrating right now on developing atomic engines for the propulsion of submarines and aircraft. We are much farther along on the submarine reactor than we are on the aircraft one, but I am sure in my own mind that eventually we are going to have both. And as a special bonus we are going to pick up a lot of technical know-how that will help us immeasurably in cutting the costs of atomic power for commercial use. What we are doing, essentially, is charging a good share of the high developmental costs of power reactors to national security, and, in the process, getting at the earliest date possible a kind of propulsion unit that will reduce almost to the vanishing point the dependence of naval vessels and military aircraft upon bases of fuel supply.

Reactor development work—I think quite naturally—has attracted the interest of private industrial groups concerned with the production of electrical power. This is a healthy development, I believe, and we intend to do everything we can—consistent with the requirements of national security—to work with these groups toward our mutual objectives. We have tried to work as closely as possible with them in the past, and we plan to increase this cooperation in the future. In the past, for example, we have had the benefit of the wise counsel of an industrial advisory group headed by Mr. James W. Parker, of the Detroit Edison Co., which submitted some very valuable recommendations to us about 2 years ago. At present, we are working closely with our ad hoc advisory committee on cooperation between the electric power industry and the AEC, which is headed

by Mr. Philip Sporn, president of the American Gas & Electric Co., here in New York, and includes in its membership Mr. Edward Morehouse, vice president of the General Public Utilities Co., of New York. Mr. Sporn's committee has recently submitted to us a very thought-provoking report based upon a 2-year survey of our program. We are presently giving some intensive study to this report, and we expect to respond to it publicly sometime in the near future.

We are also, as many of you probably know, presently entering into agreements with the Monsanto Chemical Co., Union Electric of Missouri, Detroit Edison Co., the Dow Chemical Co., the Commonwealth Edison Co., the Public Service Co. of Northern Illinois, the Pacific Gas & Electric Co., and the Bechtel Corp., whereby representatives of these firms, organized into four working groups, will be given an opportunity to come into our program and study the practicability of private industry building and operating reactors to produce plutonium for the Government and power for industry at the same time, thus presumably reducing the cost of both. There is a lot of merit to this idea, and we're going to do everything we can to make it work, but I don't think the public should get the impression that these firms are going to be able to walk into our laboratories, stay about 6 months or so, pick up a few tricks of the trade, and then be able to go out and build economically feasible power reactors. It isn't going to be as simple as that. There is a great deal of technological, engineering, and design work that needs to be done in the reactor field before atomic energy will contribute very much to the over-all power supply of this country.

Far from being a producer of power today, atomic energy is actually one of the Nation's largest consumers, and the balance will be on the debit side for a long time to come. It has been estimated, for example, that our power requirements by the middle of 1953 will amount to about 2½ percent of the total installed electric power capacity of the United States—an amount equal to around 85 percent of the production capacity of the Consolidated Edison Co. here in New York.

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70. ADVISORY COMMITTEE OF ELECTRIC POWER INDUSTRY SUBMITS REPORT TO ATOMIC ENERGY COMMISSION

(United States Atomic Energy Commission, Washington 25, D. C., No. 382, June 22, 1951)

The ad hoc advisory committee on cooperation between the electric power industry and the Atomic Energy Commission has submitted a report making recommendations for continued studies of areas of mutual interest to the industry and the Commission. In particular the ad hoc committee recommended the formation of a permanent advisory committee.

In acknowledging the report, Gordon Dean, AEC Chairman, asked the committee for suggestions as to terms of reference and organization for the proposed permanent committee. Mr. Dean also stated that the Commission is now exploring the entire field of industrial relationships in order to devise appropriate methods for encouraging and facilitating wider industrial participation in the natonal atomic energy program.

Philip Sporn, president, American Gas & Electric Co., was designated chairman of the ad hoc committee, set up by Commission action on July 28, 1949. E. W. Morehouse, General Public Utilities Corp., and Walton Seymour, then of the Program Division, United States Department of the Interior, and present adviser on power problems to the Economic Cooperation Administration, were appointed as members.

In making its survey the ad hoc committee held numerous discussions with the Commission and members of its staff and visited atomic energy installations at the Argonne, Oak Ridge, and Brookhaven National Laboratories, the Hanford Works, the Knolls Atomic Power Laboratory, Schenectady, and the Bettis Field Laboratory, Pittsburgh.

The full texts of the report of the ad hoc committee and of the letter from Mr. Dean to Mr. Sporn concerning the report are attached.

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71. A SKEPTICAL CHEMIST LOOKS INTO THE CRYSTAL BALL

An Address by Dr. James Bryant Conant, President of Harvard University and Honorary President of the Twelfth International Congress of Pure and Applied Chemistry, at the Ceremonial Session of the American Chemical Society Diamond Jubilee Meeting, New York, N. Y., September 5, 1951

An anniversary celebration is a time for reviewing the past or prophesying the future. As the title of my remarks indicates I have chosen the latter course. In so doing I have saved myself from a vast amount of historical investigation and you ladies and gentlemen from the tedium of a lengthy talk. For to do justice to the progress of American chemistry in the last 75 years would require a minimum of 3 hours. (And I might note parenthetically that 75 years ago a speaker honored with an assignment such as mine would have been expected to deliver an oration of approximately this length.) Not only would a look backward have required more time than any present-day audience would permit, but the temptation to tell personal anecdotes would have been irresistible. For it is nearly half of a century—45 years to be exact—since I started the study of chemistry; while I cannot claim to have been present at the birth of the American Chemical Society, I certainly knew the organization when it was very young. One story only from a former era I shall inflict upon you because it seems to me symbolic of the changes which have occurred within this century with respect to our profession. It represents a bench mark in the history of American science and society, so to speak.

When this country entered World War I it so happened that a leading professor of chemistry was a relative of the then Secretary of War. Taking advantage of the fact he called on him in the first week after war was declared to offer on behalf of the American chemists the services of the profession to aid in the war effort. The Secretary said he would look into the matter and asked his caller to return a day later. When he did so the Secretary of War thanked him once again for his offer of assistance, asked him to transmit the thanks to his fellow chemists, but said it would be unnecessary to accept the proffered assistance because on looking into the matter he found the War Department had a chemist.

The story may well be apocryphal, but, nevertheless, in essence true. If Secretary Baker made any such remark in 1916, he was only a little behind the times. For at the turn of the century neither the Government nor industry in the United States was employing more than a handful of trained chemists. Today the numbers are counted in the tends of thousands. Fifty years ago the only positions available for the few rare individuals who from time to time obtained the H. D. degree were teaching positions in the colleges. To lay we graduate annually a thousand and the Nation clamors for more. In 1902 chemical engineering had not developed as a profession. Today there is a great shortage of chemical engineers in spite of the fact that more than 15,000 have been trained in the last 5 years. In short, the growth of the chemical profession within the lifetime of many of us here has been one of the amazing social phenomena of our times. It takes no crystal ball to show that this chemical revolution will affect the balance of the century. Whether the curve will continue to mount at the same rate of annual change is an open question; but that there will be vastly more members of this Nation who were trained as chemists and chemical engineers in 2001 than there are now in 1951 seems to be one of the few certainties of the future. Notice I define the members of our profession in terms of their specialized education, not their employment. For one of the highly significant aspects of the development of chemistry in the last 100 years in all countries, but particularly here in the United States, is the way chemists have infiltrated into all sorts of positions in scienific and industrial life. This process will continue. The line between chemistry and the other natural sciences will surely become less definite as time goes on. The wise comprehensive policy of the American Chemical Society long ago was based on the central position of chemistry in the applied sciences. Therefore, in terms of the all-embracing definition of chemistry, pure and applied, characteristic of this organization one is safe in predicting that the work of the chemist in the United States has only just begun. The breadth of his scientific training and the strategic position of his science will make him one of he key figures in an urbanized, mechanized society depend-

ent for its very life on the careful control of a multitude of chemical reactions. All of which is easy to foresee—all of which, by the way, places heavy responsibilities on those concerned with the education of chemists and chemical engineers. For the overtones of our technological civilization will in no small measure depend on the value judgments of those who build and operate the industrial plants. If time permitted and the occasion were more appropriate, I would intrude on your attention a pet educational hobby of mine, namely, the role of history in liberalizing the education of the scientist and engineer. For the proper study of history—not the memorizing of names and dates, but a deep study of some significant periods—may be the best introduction to the vagaries of human nature. In the words of a seventeenth-century scholar, John Selden, "it may so accumulate years to us as though we had lived even from the beginning of time."

But let me turn to my crystal ball and try and glimpse the outlines of the balance of the twentieth century. In so doing I wrap the mantle of Robert Boyle around me, for he was the original skeptical chemist, you will recall. He was skeptical of the claims of the alchemist, and I shall follow in his footsteps to the extent of questioning the prophecies of some of the modern alchemists—our friends the atomic physicists. For I see in my crystal ball—to be sure, a plastic one, as befits a chemical age—I see in this instrument of prophecy neither an atomic holocaust nor the golden abundance of an atomic age. On the contrary, I see worried humanity endeavoring by one political device after another to find a way out of the atomic age. And by the end of the century this appears to have been accomplished, but neither through the triumph of totalitarianism nor by the advent of world government.

Unless my readings are vitiated by a huge systematic error, the next 50 years prove that human nature is tough and unyielding to a high degree. Neither the forces of good nor evil prevail to the extent that has been prophesied by some writers in the last few years. The year 1984, for example, does not glare with menace in my crystal ball. Men and women still continue to be unregimented in many portions of the world. Paris, Berlin, London, New York, Moscow still stand physically undamaged by any enemy action since World War II. They still represent focal points for diverse national outlooks, though the alinement has shifted first one way and then another since 1951. The Marx-Lenin dogmas are still honored in vast areas, but so too are the watchwords of the eighteenth-century French and American Revolutions: Liberty, equality, fraternity. But time and local conditions have greatly modified the operational meaning of both the philosophies of dialectical materialism and Christian rationalism. As to the philosophical presuppositions which underlie that extraordinary social and political phenomenon of the second half of the twentieth century, the awakening of the Far East, they cannot even be suggested to a midcentury audience of westerners.

The fine structure of the future is beyond the resolving power of my equipment. That I may as well confess. Therefore, the new scientific discoveries, the new theories, the various minor revolutions in physics and inorganic chemistry are not discernible. As to those major revolutions in biochemistry, which by 1985 has become the recognized successor to what was once called biology, to these epochal events I need only allude in passing. What must be described are the slow but steady changes in the production of energy and food. The era of liquid fossil fuels is by the close of the century coming to an end, and the worry about future coal supplies is increasing. For reasons I will explain in a moment, atomic energy has not proved to be an expedient way of lengthening the period in which man taps the sources of energy stored in the earth's crust. Solar energy, on the other hand, is already of significance by the time the American Chemical Society celebrates its one-hundredth anniversary, and by the end of the century is the dominating factor in the production of industrial power. The practical utilization of this inexhaustible source of energy, together with the great changes in the production of food, has already had enormous effects on the economic and hence political relation of nations. With cheap power the economical production of fresh water from sea water became a reality. This was about 1985, and made more than one desert adjacent to a seacoast a garden spot. This last statement may seem to some of you altogether incredible. Let me, therefore, insert at this point a technical footnote, so to speak. You must understand that my apparatus which forecasts the future operates on a special principle. I feed into it certain ideas which might lead to revolutionary innovations at least in theory but are now regarded as impossible. The machine then scans the future decade by decade on the frequency of the idea in question. If the results were not at times

surprising, there would be little use of such a piece of equipment, I am sure you as scientists will all agree. I might note parenthetically that it is an interesting fact that as regards the possibility of distilling fresh water from the ocean, no one has publicized the well-known fact that in theory the energy requirements are extremely low. For example, 1 gallon of gasoline provides on combustion somewhat more energy than that theoretically required to distill 9,000 gallons of fresh water from the ocean. (Notice I say "energy," not "heat," for as many of you are well aware it is mechanical energy that is required in the modern compression stills.) A corresponding theoretical figure which has been given wide publicity is the energy content of a few grams of uranium 235 which are said to contain enough atomic energy to drive the *Queen Elizabeth* around the world. The one figure has perhaps as much relevance to future practice as the other.

But let me return to the question of the future of agriculture. The use of new techniques has made the world food situation in 1999 something quite different from what it was 50 years before.

These alterations, coupled with the discoveries about the relation of dietary factors to the birth rate and the rapid rise in the standards of living in nations once overcrowded, seem to provide the new century—the twenty-first—with an answer to Malthus. The problem of overpopulation, while not solved, promises to be in hand before 2050. This last forecast may seem to you clear evidence that my prophetic machinery has gone wrong, that my plastic crystal ball is cracked. But let me add a microphone to my equipment and listen in to what people are saying about this subject as the twenty-first century dawns. They date the changed attitude toward population to the year 1951 when Nehru advocated the establishment of birth-control clinics in India and in 1961 when the biochemists made available cheap and harmless antifertility components to be added as one saw fit to the diet. As the decades went by and the twentieth century drew to a close, the attitude of the religious leaders of the world on this subject, so they say, completely altered without any diminution of religious feeling.

Turning to fuels, I find that from carbon monoxide and hydrogen, the chemist was producing not only liquid fuels but all manner of chemicals early in the second half of the twentieth century. This revolution in industrial chemistry, by the way, led to the premature senility of more than one teacher of organic chemistry, for in place of the orthodox transformations the rebellious student now substitutes "process gas" plus a suitable catalyst and who can say he is wrong? I note in passing that by 1990 the beverage industry is based entirely on synthetic ethyl alcohol, microorganisms being used only for a minor fermentation to give flavor as is now the case in producing sherry. Carbohydrates are used no longer for producing beer or wine or distilled spirits.

The problem of conserving the fossil fuels still left has become closely related to the problem of the economic production of carbon monoxide. Each area of the world came up with different answers, but as the century came to a close those answers appeared to be converging. The underground gasification of coal, the conversion of cheap crops into process gas are just two of the ways found for supplying the chemical factories of each nation with adequate raw material. The so-called extractive industries are now transformed into chemical industries, the completion of a revolution which started in the United States after World War I, when chemical engineering entered the petroleum industry.

But how did the industrialized nations of the world avoid deindustrializing each other by atomic bombs, you may inquire? Only by the narrowest of margins, is the answer; and only because time and again when one side or the other was about to take the plunge during the period of intensive armament that preceded the great settlement, the expert military advisers could not guarantee ultimate success. Of course, the turning point was in 1950, the first year when collective security became a reality. For when the free world had once made up its mind to meet each type of military threat of the Soviet Union with a defense against that threat and no longer relied on the magic of atomic bombs, from that moment on hopes for an eventual disarmament revived. By the middle of the 1950's, I see balanced forces again at the disposal of the Atlantic Treaty Nations. It is then clear in Moscow that there can be no easy march to the channel ports. To be sure, for a decade or more the series of battles in different parts of the globe and the economic sanctions had time and again nearly precipitated world war III. People in the United States and in Russia had become somewhat accustomed to living under the shadow of the twentieth century volcano—atomic bombs. But after years of such anxiety and with the economic power of the

free world backed by some measure of political stability, the time to consider a way out of the atomic age had clearly come.

Unless my observations are in error, I find the 1960's a time when constructive steps away from war are first being taken. Fifteen or twenty years after the first atomic bomb was fired, a sober appraisal of the debits and credits of the exploitation of atomic fission had led people to decide the game was not worth the candle. Of course, experimental plants were producing somewhat more power from controlled atomic reactions than was consumed in the operation of the complex process, but the disposal of the waste products had presented gigantic problems—problems to be lived with for generations. The capital investment was very great. But quite apart from the technical difficulties there was the overriding fact that the potential military applications of atomic energy were inherently inimical to the very nations that controlled the weapons. A self-denying ordinance seemed but common sense. Once the illusion of prosperity for all through the splitting of the atom vanished from people's minds, the air began to clear. The dividends from the great discoveries of the forties were recognized to have been the introduction of powerful new tools of investigation in both pure and applied fields of chemistry. The success of a vast technical undertaking to make atomic weapons showed what could be done in other radical departures. The rapid progress in the utilization of solar energy is thus seen as a consequence of the atomic energy development.

The mood 15 or 20 years from now, as I glimpse it, is conditioned by a set of technological military and political factors quite different from those operating in the year 1951. Just enough agreement is then possible in the United Nations to proceed with gradual disarmament. Just enough inspection proves to be possible to enable even the most suspicious to trust an international guaranty to the effect that there is no assemblage anywhere of vast amounts of fissionable materials and of guided missiles. The existing stocks of fissionable materials are put beyond the immediate reach of any nation. The possibility of wholesale atomic raids by a nation which treacherously repudiates the treaty is eliminated; sufficient information at least can be guaranteed to settle men's doubts about that sort of war. (And by the 1960's I see people unconcerned about the existence of a few bombs more or less in another nation's arsenal.) But most significant of all, people by then are beginning to realize that it is protection against invasion by foreign soldiers that is of prime importance. If frontiers can be held against aggression, then atomic bomb threats to industrialized centers are not only unnecessary but outmoded. Clearly, an industrialized civilization could destroy itself and thus leave the world to those peoples not yet heavily urbanized and mechanized. But people are saying, as I listen in on the 1960's, "What sense is there in that?" Admittedly the individual components of this civilization are distrustful of each other. Admittedly each must protect its integrity if need be by force of arms, but why continue to live on an artificial earthquake fault of one's own making?

The date of the great settlement is not clear in my reading of the future, but sometime between 1960 and 1980, the climate of opinion alters. The rearmament of the free world has done its work. Armies, navies, planes are still on hand but the trend is toward less rather than more military power. So I see the physicists and engineers at that time relieved of a terrible responsibility and gladly turning to labors more congenial than making fission and fusion bombs or guided missiles. I see the chemists in increasing numbers continuing to crowd into fields once reserved for others, and thus an era of peace and prosperity really begins to dawn.

So much for prophecy. Now in conclusion, let me come down to earth. The world of science has passed through a shattering experience in the last 10 years. Hundreds of man-years of scientific and technical genius have been spent on improving instruments of war. And now once again the process is accelerating. The hopes for a decreasing emphasis on military force born in 1945 have proved illusory. The free world is once more threatened by totalitarian aggression. We now realize that in this century at least free men can protect themselves against disaster only by facing the possibilities of war realistically. Peace cannot be achieved through magic either physical or political. We have invented machines to do much of the labor once performed by slaves or serfs, but there is no mechanical or scientific substitute for those personal qualities on which our liberties are based. Ideas must, if need be, be fought for. Frontiers must be protected against invasion by human beings ready to die if necessary. And those frontiers are for us in the United States the world frontiers of freedom.

When World War II ended we believed in miracles—some in the miracles of science that would protect us militarily with a minimum of inconvenience, certainly without blood or tears—others believed in international miracles which have not come to pass.

It is easy to be defeatists about the prospects for peace and freedom and to forecast the future only in terms of a global war. I have ventured to do otherwise and with all sincerity. To my mind the prospects are far more hopeful than they were 2 years ago. The peoples of the free world have been awakened from their dreams of an easy peace, they have faced up to the realities of the mid-twentieth century. Before long they will be armed and ready. When that day comes the fear of Communist aggression will cease to haunt Western Europe. When that day comes, one can begin to talk about a real settlement of the international situation. Ideas that must now be regarded as utopian will once again have vitality and meaning. All this may seem to the pessimists among you, those who believe a third world war to be inevitable, as so much wishful thinking. But because I have so much confidence in what freemen can accomplish when once aroused, I believe that in spite of grim years ahead this second half of the twentieth century may yet prove to be a period of gradual disarmament and peace.

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72. UNITED STATES AIR FORCE PRESS RELEASE, WASHINGTON, D. C., SEPTEMBER 5, 1951

A development contract for an atomic-powered airplane has been awarded to Consolidated Vultee Aircraft Corp., San Diego, Calif., the United States Air Force announces today. Primary responsibility of the firm under the contract will be development of an airframe. The General Electric Co. is to develop the nuclear-powered engine under a contract with the Air Force, negotiations for which were announced last February. Negotiations with General Electric also were announced by the United States Atomic Energy Commission last March 24 concerning a contract for associated work on a nuclear reactor for aircraft. Both General Electric and Consolidated will work closely with the Air Force and the Atomic Energy Commission on the project.

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73. INDUSTRIAL PROMISE OF INDUSTRIAL ENERGY

Remarks by Gordon Dean, Chairman, United States Atomic Energy Commission, Before the Indiana Convention of Electric Power Engineers, French Lick, Ind., October 12, 1951

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The reactor development work which we have been carrying on within the Commission program has recently reached the state where it has attracted the interest of private industry. This, in our view, is a natural and healthy development, and we intend to do everything we can to work with industry—consistent with our national security responsibilities—in the achievement of our mutual objectives. An example of the kind of industry-AEC cooperation that is being carried on is the agreements we made some months ago with eight private firms—including the Public Service Co. of Northern Illinois, the Detroit Edison Co., and the Commonwealth Edison Co.—whereby representatives of industry have come into our program to study the practicability of industry building and operating power-producing reactors with their own money. What has interested industry is the fact that the fissionable material, plutonium—for which there is a great demand in the Government for use in weapons manufacture—is made in reactors, and these firms feel that if they can build reacators that produce plutonium for the Government and power for commercial use simultaneously, they may possibly make the power they produce economically competitive.

There is a lot of merit to this idea, and we are going to do all we can to help make it work. If it is some day placed into effect, however, it seems to be apparent, under the atomic energy law as it is now written, that the fissionable fuels for these private reactors would have to come from the Commission, and the Commission would probably have to retain title to them under the law.

Payment to the companies for the plutonium produced would therefore probably have to be in some such form as a fee. The size of this fee would, of course, have an extremely important bearing on the price at which the power the reactors produced could be sold. If the fee were high the power could be sold more cheaply, and vice versa. If the fee had to be so high, however, that it exceeded the cost of plutonium produced in the Government's own facilities, what we would have, in effect, would be a Government subsidy of these private plants. What would be ideal, of course, would be to have the fee fall below our own normal production costs, and still have the power be competitive. Under these conditions, the whole enterprise would appear to constitute a real contribution to both peacetime welfare and national security, provided it did not otherwise interfere with the military side of our program. In any event, the reports that will be brought forth by the studies currently going on—whether they be favorable or unfavorable—will receive the most careful kind of consideration.

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74. ATOMIC WEAPONS AND NATIONAL DEFENSE

The University of Chicago Round Table: Joseph E. Mayer, Frederick Seitz, and Harold C. Urey, November 25, 1951

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Dr. UREY. I myself feel that there has been a lack of enthusiasm for the development of useful atomic power. I spent some time at Oak Ridge last summer myself, working on this problem. It is a difficult problem; but it does not look impossible to me that useful atomic power can be secured. And I returned to Chicago to find prominent members of the Scientific Advisory Committee advising the public that all this sort of effort is not of much value. Dr. James B. Conant made a speech in New York, saying that by 1960 we would all drop the development of atomic power as something which was not worth a candle; and Dr. Lee DuBridge of the California Institute of Technology says that it will be 30 years before atomic power can be developed. Other members of this Scientific Advisory Committee say that the development of atomic power is not worth while. All these things remind me of the fact that this Committee was not the one to push the development of the H-bomb. I believe that there has been a lack of enthusiasm by people who are advising the Government on this subject which is wholly unjustified, and it might be well if such a position were revised in the future.

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75. INDUSTRY AND THE ATOM

Remarks Prepared by T. Keith Glennan, Commissioner, United States Atomic Energy Commission, for Delivery at the Annual Meeting of the American Society of Mechanical Engineers, Atlantic City, N. J., November 29, 1951

There are several reasons why we in the Atomic Energy Commission welcome an opportunity periodically to discuss our problems with the American Society of Mechanical Engineers.

As a group, mechanical engineers, using the ASME as their vehicle for expression, have taken an active and constructive role in developing our national atomic program. Senator Brien McMahon, now Chairman of the Joint Congressional Committee on Atomic Energy, came to you for advice back in 1946 during the debate on the bill that today is the basic law governing AEC operations. Our first Chairman, David E. Lilienthal, addressed your annual meeting in 1947. Two years later, the ASME made some thoughtful proposals for more effective participation by industry in the activities of the AEC. These plans produced some concrete results, though they were not adopted in toto.

Your request that a member of the Commission address you at this meeting is evidence of your continuing interest. As we contemplate the possibility of still another increase in our atomic-energy production program, we stand in need, once more, of your interest and thoughtful counsel, both as individuals and as members of a great engineering and management group.

One of the reasons for this is the fact that probably the most striking aspect of engineering today is the steady movement of members of the profession into the management of industry. This is particularly noticeable in the atom business. We consider the AEC to be primarily an industrial operation and this development is certainly evident to anyone who takes the time to examine it. Our General Manager and the Deputy and Assistant General Managers are engineers. Each of the 10 Managers of Operations is an engineer. Two of the five Commissioners were trained as engineers. Thus, the engineering viewpoint and approach bulk large in two ways: In the making of AEC policy and in the day-to-day supervision of atomic-energy operations.

The basic operating principle of the AEC is to accomplish its production goals through the genius of American industry. As the engineer assumes an increasingly important role in the leadership of both industry and the atomic-energy program, it seems worth while, then, to discuss with you—as engineers, managers, and professional men—some aspects of the present and future role of industry and business in this great new activity. My own concern about the overlong continuation of the present governmentally dominated industrial-governmental relationship for the prosecution of the atomic program makes this opportunity for discussion with you attractive to me.

Perhaps we can best get into this by asking some questions and then suggesting answers that may stimulate further study and debate on this subject in your local chapters as you return to your home cities. Some appropriate questions, I would say, would be:

1. How did the AEC get its present contractors?
2. What are the handicaps of working in the atomic program?
3. What are the incentives?
4. What is the AEC doing to help industry and management to understand the atom business?
5. What should be the role of private industrial enterprise in the future of a rapidly growing Government enterprise—an enterprise which takes on many of the aspects of a monopoly created by law—an enterprise upon which much of the future security and well-being of this Nation may substantially depend?

Most of the distinguished names in American industry are to be found on the roster of prime contractors of the AEC. Many of the 500 major contractors are represented in this audience. As a group, these firms make up a substantial segment of the top industrial organizations in America. And more companies are coming in as the program expands. How, then, did these firms get into this business and why are they working for the Government?

I would not presume to try to answer for each of these industrial contractors. However, I have made it a point to raise the question with several of those who have been in it for a long period of time; and to raise the question also with the general manager, the operating managers at the field offices, and with the directors of program divisions at headquarters. It is important to have the answers to this question for there is every evidence that the dedication of the managerial skill, the operating competence, and the cost-cutting know-how of industrial contractors, large and small, has played a major part in making this Nation's atomic program as successful as it has been. If the atom business is to thrive and prosper on a prospectively broader scale, the Nation must command more rather than less of such dedication and service on the part of industry.

In brief, the responses to my inquiries have indicated that two motives have dominated the decisions of industrial management to accept the uncertainties of Federal service in the atomic-energy program—and both of these motives continue to satisfy the newcomer to the business today. The first was expressed rather well by Dr. George Felbeck of Union Carbon & Carbide in a discussion sponsored by the American Chemical Society in Washington just last week when he said: "Why take one of these Government jobs, and after you have it why stay with it? Corporations as we know them are creations of the American system and they exist and flourish because of that system. If we lose a war, we know the system will change and that corporations will cease to exist. It is simply a question of survival. The men in Government are devoting their lives to the preservation of the environment in which we can do business. There is no privilege reserved to corporations or corporation employees which allows them to shirk their duties of citizenship. It is the duty of every corporation to make those contributions to the defense of this country which it is qualified to make."

The second motive has arisen out of the feeling that it is prudent and forehanded to become conversant with and facile in this new technology and science which may influence so widely the future course of engineering and production.

But more of this later—let's look at some of the handicaps or deterrents to industrial participation in this type of governmental-industrial relationship.

First, and most obvious, is the fact that the atom business is a Government-owned operation. To quote from the magazine Business Week in one of its 1950 issues—"Atomic energy under the McMahon Act is an island of socialism in a sea of private enterprise. Never before has so potentially important a technology been subjected so completely to public control."

This is hardly the kind of an atmosphere that would sound attractive to private enterprise. This was particularly true back in 1947 when industry had the pleasant prospect of satisfying the pent-up demand for the billions and billions worth of civilian goods denied a high-earning, large-saving American population during 6 years of war and reconversion.

The fact that the atomic-energy program is a governmental monopoly means that—for industry—the *normal* profit incentive is lacking. For the same amount of talent and effort put into its own business, any industrial concern would expect to earn profits, even after taxes, far in excess of the fees allowed under an AEC contract. It must be remembered, of course, that industry makes little or no financial investment in the atom business and takes no very great risk of substantial financial loss. Nevertheless, a very real investment is exacted of the contractor in terms of the qualified men required to be assigned to the job. Top technical and management brains are necessary even though they must be diverted from other work. Taking these facts into account and recognizing its obligation to the taxpayer—the AEC sets the fees paid for management services at the lowest figure that can be negotiated. Under the conditions that have existed to date this system has seemed about as fair as any that could be devised. Nevertheless, the normal (and I emphasize *normal*) profit incentive is lacking.

A second deterrent to private participation is the patent situation. Under the Atomic Energy Act, inventions and discoveries made in connection with the work become restricted data if connected with fissionable material or weapons or become public property available for nonexclusive licensing if they are nonmilitary in nature and declassified.

There appear to be two viewpoints on this particular problem. One group feels that if normal patent incentives were restored throughout the atomic field, private money would flow in and development would go forward in a manner more businesslike, faster, and cheaper. Equipment and processes developed in the atom business would be available for use in the contractor's regular business. There are some who see in the patent clauses of the Atomic Energy Act an attack on the patent system generally.

Opposing this view is the one that suggests that there has been little possibility of private industry making much of an investment in the atom on a risk basis. The price tag has been high and the market extremely limited and uncertain. Weapons uses seem inevitably to dominate the field in the foreseeable future. This second viewpoint holds that when the time arrives for commercialization of some aspects of the atom business—everyone will be on even terms. There will be no special legal or economic privileges deriving from patent advantages held by the insiders—the AEC contractors. You will have to take your choice, but here again remember that public money is involved.

A third handicap is the vital security regulations that must be added to the usual problem of Government red tape. This causes exasperating delays in building up staffs of personnel who must be cleared after time-consuming background investigations. It requires the expenditure of millions of public dollars that must appear wasteful to the average hard-headed industrialist, until he has been educated on the importance of security. On the red tape side—well—need one say more about this? And yet much of it is necessary in the interest of accounting to the taxpayer even as large industry tends to become a victim of its own red tape in the interest of accounting to the stockholders or the trustees.

There is also the fact that health and safety standards are much more rigid in atomic work than in normal industrial operations. To an outsider not familiar with the scope of radiation hazards, the AEC precautions may seem unrealistic. Potentially, the atom business is one of the most dangerous in the world. In practice, it is one of the safest. But the time-consuming precautions require men and may make a potential contractor hesitate before committing his firm to an AEC contract.

Given the lack of normal profits, the absence of patent protection, the unusual expense in terms of manpower, the complex security regulations, unusual health standards and a fair supply of red tape, one might well ask why private enter-

prise hasn't pulled out of the atom business entirely and let Uncle Sam run it as best he could with Government employees. As you may know, this had been proposed by certain groups in this country. We in the AEC feel that any approximation of such a course would be a national calamity. And we believe that there are reasons why this has not happened.

Those contractors who shared the load during the war acted without hesitation under the most impelling of motives—a patriotic sense of duty to the Nation. But they could have withdrawn at the end of the war. A few did but most of them are still in the program. Here are some reasons for their action in continuing—reasons which I repeat, I have heard from the men who head the larger of our contracting companies.

Prestige might be put near the top of any list of incentives. It is sometimes difficult for critics of the capitalist system to believe that the industrialist has any interest other than profits. You and I know that pride of achievement is one of the driving forces that has made this country the greatest industrial nation in history.

When the war ended within a fortnight after atom bombs fell on Hiroshima and Nagasaki, there was glory for all who had a part in the magnificent gamble. Since then the record of the AEC in achievement, in my judgment, has been good. People, by and large, think that the progress in atomic weapons under the management of the AEC has constituted a significant contribution to national security and the preservation of a degree of world peace. This has meant good will and prestige for those industries that have made this progress possible. I believe this factor is most persuasive in encouraging other segments of industry to come into the program.

Another tangible asset is the improvement in technical resources and staff that comes with participation. This is the other side of the coin which complains about diversion of top men from a contractor's regular private business. The atom industry is still a challenge; it retains the air of—and it is indeed—an adventure; it appeals to young minds despite the distasteful aspects of some elements of the security restrictions. AEC contractors thus have a decided advantage in building up more competent technical staffs.

The AEC supports a policy of trying out new processes, new equipment, new gadgets. We are still young enough to be unorthodox when such a course seems to promise progress or cut costs. This appeals to the good engineer. He is called the enemy of error and at many stages of our work, trial and error is the only method of solving a complex problem. All these factors make the atom business appealing to many industrial leaders and can result in adding great strength to the resources of any organization.

Finally, there is the idea of "getting in on the ground floor," which I mentioned earlier. No industrialist knows just what the atom will mean to him. But he doesn't want to be left behind when the parade starts. Admittedly, the parade hasn't started yet, but from time to time, one catches the distant rumble of the processional drums. There are enough new things being done in chemistry, metallurgy, electronics, and a dozen other areas of this business to make this desire to be in on the ground floor a powerful factor in attracting new blood to the program.

I think it is fair to put it in the record at this point that the AEC has taken a number of steps to make things as attractive as possible to private enterprise. The over-all Government ownership and control is a matter of law. Continuation and expansion of the contract system has been a matter of policy. The agency has limited the role of the Government largely to policy, security, standards of performance, and contract administration. Proof of this is seen in the employment figures. Of more than 100,000 persons engaged directly in the program, only about 6,000 are on the AEC payroll—something on the order of 1 in 20.

Some segments of the atom business have been left almost entirely in private hands. Uranium mining is the most conspicuous example. Our atomic resources rest on the narrow base of the presently available supply of uranium. This base must be enlarged. While we continue to rely on foreign sources for a major share of ore, a remarkable increase in production has been achieved in our own country through the encouragement of private enterprise.

In addition to the setting of minimum prices for the ores—prices guaranteed for a period of years—one might cite the Commission action in publishing of the handbook Prospecting for Uranium of which 75,000 copies have been sold. Then, too, a chain of assay stations has been established where more than 1,000 samples of ore are processed each month.

In the isotope field, the AEC is encouraging free enterprise in a number of areas. The manufacture of special isotope handling and processing equipment is a fast-

growing industry and is almost completely in private hands. This has led to the building up of priavte analytical research staffs for consultation and development and to servicing of these privately manufactured devices. The dozens of companies in this new field compete naturally and normally for the available business and seek to develop new accounts. Collectively, these companies are playing an important part in widening the application of radioisotopes in many fields, especially in industry.

Another AEC policy has been to turn over for commercial development some of the processes proved out in the laboratory. The MED did this with uranium processing during the war. Industry has reciprocated. Mallinckrodt developed a continuous processing system which replaced the batch method for certain stages in the making of uranium metal. Other contractors have taken devices and systems developed successfully in AEC laboratories and improved them in industrial operation. Presently, we are attempting to interest private companies in the production of zirconium metal and are willing to guarantee a market for a period of years as an incentive.

A positive technical information program has been developed by the AEC. The lack of information was one of the principal points emphasized in an excellent survey made by a special industrial advisory group several years ago. In its summary, made in December 1948, this group said:

"The essential precondition to increased industrial participation, is knowledge of the subject so that industry may recognize opportunities to take part as they arise * * * still secret information which is properly declassifiable and of special interest to industry should be declassified and published."

This need has been met in a number of ways. Following the report of the industrial advisory group, the Commission asked representative editors of the professional engineering society journals and of the business press to serve as an ad hoc advisory committee to investigate whether technical information that would aid American industry is being needlessly classified, and to recommend ways and means for dissemination of unclassified and declassified information to industry generally. S. A. Tucker, the manager of publications for ASME, served as a member of this committee. The committee has investigated two collections of data—that in the patent files and that clustering around the electromagnetic separation plant at Oak Ridge. They came to the conclusion that the AEC record of declassification of technical information is fairly good—that little is being held back that would greatly aid American industry.

Early this month we took the second step—the strengthening of our information distributing system. The ad hoc committee met with representatives of the AEC contractors, the field offices of AEC, and the Washington program divisions. They hammered out together recommendations for speeding up the flow of information through the professional journals and the business press.

Starting with the July 1949 issue, each of the semiannual reports to Congress has given exhaustive treatment to a specific field of atomic-energy development. Special reports such as the 3-year summary of isotope distribution and use and a handbook on aerosols have been issued.

Some 40 libraries have been made repositories for all unclassified and declassified reports. These collections now run to about 4,000 papers, and should increase at the rate of about 1,000 a year. A special bibliography of some 250 papers of special interest to industry was compiled in the spring of 1949.

Over 300 patents are now available for license to industry. They cover a wide range of processes and inventions. AEC-printed scientific reports are available at nominal prices through the Office of Technical Services of the Department of Commerce. The monthly average of sales is between 500 and 600, of which roughly one-half are requests from private industrial laboratories.

Of special interest to you as engineers is the fact that a source book on engineering in atomic energy is to be prepared under an AEC contract. It will be edited by Dr. Samuel Glasstone, the well-known textbook author, and will be a companion volume to his excellent Sourcebook on Atomic Energy.

I believe you will agree that all this adds up to a rather impressive program of information which should be of assistance to industry and management.

One of the maddening bottlenecks we have mentioned is the lack of trained personnel in the science and technology of this new business.

The AEC does not wish or feel qualified to substitute for or replace the colleges in engineering education. But it will take time for nuclear technology to be integrated generally into the curricula of engineering schools. In the meantime, the AEC has started a stopgap operation which grew out of one of the recommendations made by the ASME in 1949.

The classified Reactor School of Technology began operation at Oak Ridge, Tenn., with 43 students enrolled for the inaugural 1950–51 session. Only four

of these were from industry. The second year began in September with 75 enrolled for the 12-month course. This time there are 24 students from industry. Their employers will pay their salaries while they study, with the AEC providing the facilities and the faculty.

Another encouraging factor was noted in the recent unclassified symposium on atomic energy engineering held also at Oak Ridge. More than 500 attended the 2 weeks of lectures and among these were 57 from industrial organizations not now on the AEC list of contractors.

Another ASME suggestion was the part-time employment by AEC contractors of specialists from non-AEC concerns. This program also has been put into effect. The arrangements are made on an individual basis between the person to be employed, his company, and the AEC contractors. Thus the AEC, in some small ways, is helping to break this bottleneck of the lack of trained manpower in the scientific and engineering fields.

From this enumeration of operating policies designed to encourage more participation by industry in the atomic program, you can judge whether or not we have gone about as far as we can within the present terms of the Atomic Energy Act. Now let's take a look at the future and some of the problems of opening the door for private investment, risk taking, and profit making in atomic energy.

In its latest annual round-up, Business Week said: "As recently as a year ago you had to look hard and long to find serious interest among businessmen in atomic matters. To most of them this was something for the military, the scientists, and the Government to worry about. More than once, the AEC people have had to beat on the desks and make patriotic appeals in order to find companies willing to take on projects for it.

"Today, you can see signs of a rush to get into the field before the ground floor gets too crowded. Many companies are coming to AEC asking for assignments, and it needs only a hint of Government receptiveness to bring in more.

"For the first time, businesses are spending a little of their own money to get a toehold in the area. Several are thinking about large investments."

This was, by and large, an accurate report and there are two obvious reasons for the change in climate. First, the atom business is getting so big that it involves almost every kind of industry at some point or other. Second, as we continue to make significant strides toward the production of useful power for the propulsion of military vehicles, the prospect of central station power from atomic fuels, and other peacetime uses, becomes more exciting.

If I have one message to leave with you today, it is this: Don't sit back and wait for things to happen in the atom business. Continue to be impatient about the future and the enlargement of industrial participation on a basis that will allow your companies to earn a return on your efforts commensurate with the risk they will take. And look for the opportunities to take that risk. If you do not do this it is my opinion that you may well be witnessing the first step in the extension of governmental control over our basic industries. For this reason alone I am glad to take note of the Business Week story that I just quoted and to urge that each of you review with your companies the possibility of developing an interest in this new field.

There should be no misunderstanding, however, about this one point. The law charges the Commission to develop the use of the atom for the benefit of the Nation and mankind subject at all times to the paramount objective of promoting our common defense and security. Today this means getting on with the weapons business. This grim job we are doing and doing with a grim will. You know, however, that the process of manufacturing fissionable material is the same whether the material is to be shaped into parts of weapons or into fuel assemblies for peacetime uses. The present international situation requires that the Government continue to own and control the source materials and the finished product. Should the efforts of this and the other free nations to obtain an effective system of international control and disarmament succeed, it would appear possible and desirable to release into normal competitive channels these materials which hold such promise for the future.

Until that time arrives it is the duty and responsibility of each of us to learn as much as possible about current technology in the atom business. How else will you be able to enter the field when and as the opportunity presents itself? Let me take the time to recount briefly the steps which have been taken during the past year by alert and progressive companies willing to risk an investment in the future.

First, the Abbott Laboratories of North Chicago have leased space in the town of Oak Ridge and have a small manufacturing operation under way there for the

preparation of certain radioactive compounds of short half-life. These will be sold to hospitals and medical research laboratories.

To my knowledge, this is the first commercial operation aimed at national distribution ever to be set up in one of our atomic cities. Abbott subleased its space from an undertaking establishment and pays the same type of rent as do other local businesses. Although small in scope, it is a significant step.

Along the same line, two other corporations, Bendix Aviation of Detroit and Tracer Lab of Boston, are studying—at their own expense—the commercial feasibility of manufacturing, processing, and selling radioisotopes. A reactor large enough to manufacture a variety of radioisotopes will cost a substantial amount. The market, while large in one sense, is principally supported by Government laboratories or agencies where research is Government-financed. There would seem to be strong deterrents against any optimistic outlook here—and yet, it is just this sort of situation that I would expect an alert competitive company to accept as a real challenge.

And then, there is that most important development—atomic power. Many of you are familiar with the story. The first proposition came from Charles Thomas of Monsanto Chemical. He proposed that Monsanto—at its own expense—put a team of "cleared" scientists and engineers to work on studying our reactor program. Thomas figured his people might find a better way of building reactors that would make plutonium cheaper than the AEC can make it and make power at commercially competitive rates as a byproduct of the plutonium manufacture.

Others got interested in Monsanto's idea and as a result, the AEC has contracted with four groups of chemical and utility companies for the first phase—the study stage—of this far-reaching proposal. To date 92 persons from these companies have been cleared and 40 are working full time on the project.

The companies that will invest at least a million dollars in this very preliminary study phase are Monsanto and its associate, Union Electric, both of St. Louis; Detroit Edison and Dow Chemical of Midland, Mich.; Commonwealth Edison and the Public Service Co. of Northern Illinois, both of Chicago; and the Bechtel Corp. and the Pacific Gas & Electric Light Co., both of San Francisco.

With the exception of Monsanto and Dow, all of these are newcomers to the atomic business. Bechtel is now busy with its first AEC job—constructing the chemical processing plants at the National Reactor Testing Station in Idaho.

What will they come up with? I don't know, but I am satisfied that much of value will appear in their reports. You just can't let intelligent, aggressive engineers and management people loose in this business and draw a blank as a result of their efforts. No one of these companies will willingly throw away the money they are spending on these surveys. As a minimum, then, let's say that I am more than mildly optimistic on this deal.

Along with the activities just described we can list others in which the Commission has taken the initiative in developing normal industrial participation in portions of the atom business.

Some months ago, the AEC commissioned the Stanford Research Institute to make a survey—to conduct a "market analysis" if you wish to use the language of business—to develop industrial uses for a valuable source of atomic radiations that up to now has been an expensive economic waste. This source is the highly radioactive fission products resulting from the operation of reactors.

The Stanford group turned in a preliminary report last month. It suggests that present commercially feasible industrial uses for these waste products include the activation of phosphors for self-luminescent signs and markers; static eliminators for a variety of industrial processes; the reduction of starting voltage requirements in fluorescent light tubes and in process control instruments which incorporate a source of radiation.

Under possible future uses, providing the technology can be developed, are listed industrial radiography; cold sterilization of drugs and foods and portable low-level power sources.

In the opinion of the investigators, and I quote, "The technological and marketing problems confronting the Commission in making fission products available to industry are difficult but not insurmountable."

A second example of Commission urging is to be noted in our attempts to turn over to private hands the production of zirconium metal for which the Commission has a continuing requirement. Thinking back over the development of aluminum and titanium one may hazard a guess that zirconium, too, will find an important place in industry as the years go by. In my opinion, industrial uses will be developed more rapidly under private sponsorship than under Government control.

Thus in these several areas we have the first glimmer of possible action by private industrial concerns—private enterprise, if you will. It is too early to know any of the answers and we in the AEC are wary of prediction.

Nevertheless, what I would like to see is more industries knocking at our door and asking "What's in this for me?" and being prepared to lay money on the line to find out, like the chemical-utility groups are doing. And I say to you in the ASME—instead of depending solely on coming to us as an organization, go as individuals to the companies with which you are associated and spur them to action.

As more companies get a dollar stake in the atom business, we will have a more critical examination of the assets and liabilities of the business. This is essential if we are to get intelligent and workable answers to the questions that we will face in the future—the questions of how the military and the general civilian applications of atomic energy shall be operated and industrially developed—whether by Government monopoly or by private enterprise or by a mixture of the two. The kind of answers that the people and their policy-making representatives give to these questions will play a large part in making the kind of America that our children and grandchildren live in; and in fact the kind of a world that the coming generations around the earth shall live in. My plea this afternoon is that engineers and the management of industry give their effort and their thought to searching out and actually performing the proper role of private enterprise in atomic energy.

Unless this is done the likely thing will be that atomic energy development and operations, in the absence of any desire, any demonstration of the capabilities of private enterprise in this field, will by default continue as a Government monopoly and become more rather than less of a straight Government operation. This Nation needs its best brains and skill at work on these problems as the free world struggles to combat foreign ideologies and the aggressions which they foment. These aggressions must be opposed—they will be opposed—but let us accomplish that purpose without resorting to the methods of the aggressors—the totalitarianism that we abhor.

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76. THE ATOMIC ENERGY INDUSTRY: AN EXPERIMENT IN HYBRIDIZATION

By James R. Newman

(From the Yale Law Journal, December 1951. Reprinted by permission.)

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Observe the curious evolution of national atomic energy policy. The initial predilection was to abrogate the wartime system, to eliminate the state from all but regulatory control, and to open the new resource to private industrial exploitation. Such a policy was opposed mainly on the grounds that it would jeopardize the nation's military defenses. Thereafter control legislation was adopted removing atomic energy from the domain of private enterprise. The control agency adhered to the formal requirements of the statute but provided for private participation by means of management contracts and other devices. After a few years of experience along this line, it is now suggested that the federal monopoly is itself the principal cause of shortcoming in the production program and that, so far from private exploitation of atomic energy weakening the country militarily, the transfer of the program to competitive enterprise would fortify security. In short the Atomic Energy Act adopted in the interest of national defense is now to be repealed in the interest of national defense. Symmetrical and very neat—but not very convincing. It is prudent to doubt that the gravest defects in the program are the outgrowth of federal monopoly; it is even less reasonable to anticipate their disappearance when private business takes over. The problems of labor relations, to cite only one example, are not so easily solved. Moreover, the major social, economic, and international considerations relating to the development of atomic energy, expressly recognized in the Act itself, appear to have been forgotten in the plangent urge to instate the enterprise system. And what has happened, one may ask, to the innocent notion that the benefits of atomic energy should accrue to the nation as a whole—without the prior drain of private profits—since the resource itself was brought to fruition by public funds? Somewhere along the circular route of national policy this point got lost. Sooner or later the American people will demand to know where and why. The answer, I venture to say, will not be easy to frame.

77. EXPERIMENT IN GENERATING POWER SUCCESSFUL

(U. S. Atomic Energy Commission, Washington, D. C., No. 407, December 29, 1951)

CHICAGO, Ill., December 29.—Small amounts of electric power have been produced from heat energy released in the operation of the experimental breeder reactor, recently completed at the National Reactor Testing Station in Idaho, it was announced here today by A. Tammaro, manager of the Chicago operations office of the Atomic Energy Commission.

In a trial run on December 21 and 22, 1951, electrical power of more than 100 kilowatts was generated and used to operate the pumps and other reactor equipment and to provide light and electrical facilities for the building that houses it. Test operations will be resumed early next year after further adjustments of the reactor system.

The heat energy generated was removed from the reactor by a liquid metal at a temperature high enough to generate steam to drive the turbine.

This new reactor was designed and is being operated by the Argonne National Laboratory, Lemont, Ill.—the reactor research center run for the AEC by the University of Chicago. The tests were supervised by Laboratory Director Walter H. Zinn and Mr. H. V. Lichtenberger, the laboratory project engineer for the experimental breeder reactor.

The principal function of the breeder reactor is the long-range goal of converting nonfissionable material into fissionable material more rapidly than nuclear fuel is consumed, a process that would contribute to expansion of the current atomic-weapons program.

The power generation phase is incidental but is being carried out to secure experimental information on the handling of liquid metals at high temperatures under radioactive conditions and on the extraction of heat from a reactor in a useful manner. The system at the breeder reactor can never generate large amounts of electrical power but it does provide a useful tool for carrying out such experimental studies.

Dr. Zinn emphasized that no comparisons should be made of the cost of producing electric power from this reactor with power from conventional sources. Cost was not an essential factor in the power phase of the Idaho reactor and the experiment is in no way intended to establish the feasibility of producing electrical power economically from nuclear sources. The technical information gained, however, may be useful in the design of future reactors aimed at generating electricity at a competitive cost.

The reactor itself and its principal components were erected at the Idaho testing station by the Argonne National Laboratory. The Austin Co., Cleveland, designed the building and some of the reactor system. Construction at the site was by the Bechtel Corp., San Francisco, under the supervision of the AEC's Idaho operations office headed by L. E. Johnston.

Total construction cost was about $2,700,000. Approximately $2,500,000 was spent by the laboratory over a 4-year period for research and engineering development.

Marion W. Boyer, AEC general manager, has sent congratulations on behalf of the Commission to Dr. Zinn and his associates. He said that the successful operation of the experimental breeder is evidence of the thorough and capable work which has gone into this program.

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78. REMARKS PREPARED BY GORDON DEAN, CHAIRMAN, UNITED STATES ATOMIC ENERGY COMMISSION, FOR DELIVERY BEFORE THE CHICAGO ASSOCIATION OF COMMERCE AND INDUSTRY, HOTEL SHERMAN, CHICAGO, ILL., FEBRUARY 1, 1952

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There are many other examples of the awareness of Chicago and the Middle West in general of the potentialities of the atomic age. One of these is the series of pioneering studies now being conducted by private industry—in cooperation with the Atomic Energy Commission—to determine what, if anything, private enterprise might be doing now to get into the atomic-power business with its own money.

These significant studies are being conducted by eight industrial and electric-power companies organized into four working groups. It is worth noting, I

believe, that of these eight companies two are located in Chicago and four of the six others are located in the Middle West. The Chicago concerns are the Commonwealth Edison Co. and the Public Service Co. of Northern Illinois. The others are the Monsanto Chemical and Union Electric Cos. of St. Louis, the Dow Chemical and Detroit-Edison Cos. of Michigan, and the Bechtel Corp. and Pacific Gas & Electric Co. of San Francisco.

Essentially, the hope behind these studies is that atomic technology has reached the point where reactors can be developed to produce two products simultaneously—power and plutonium. There is an obvious commercial market for atomic power if the price at which it is sold competes favorably with the price of power produced by coal, gas, and falling water. There is also a market for plutonium, which the Government utilizes currently in the manufacture of weapons.

The hope, then, is that if plutonium can be produced for the Government and if the price received for the plutonium can be applied against the cost of producing the power, the power can be made economically competitive. If this can be done, it obviously would give private industry a chance that it otherwise might not have to get into the atomic-power business during the current high-cost developmental phase.

The Commission has only recently begun to receive the first preliminary reports of these industrial study groups. They are now being reviewed by our staff, and it is a little too early yet to say just what will come of them. We have great hopes, however, that they will lead into something that will be of considerable value to the Commission, to private industry, and to the American people.

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79. CONSTRUCTION OF SUBMARINE INTERMEDIATE REACTOR AUTHORIZED BY ATOMIC ENERGY COMMISSION

(U. S. Atomic Energy Commission, Washington, D. C., No. 412, February 21, 1952)

The United States Atomic Energy Commission has authorized immediate construction at West Milton, N. Y., of General Electric's land-based prototype of an atomic power plant for submarines.

Design and construction of this nuclear reactor is under the direct supervision of the Knolls Atomic Power Laboratory operated in Schenectady, N. Y., by the General Electric Co. for the Commission. The reactor will be located on the 4,000-acre site already owned by AEC in West Milton near Schenectady. Construction of buildings and facilities to house the reactor and related equipment will be accomplished by direct contracts under the Schenectady Operations Office of the Commission.

The prototype will be used for final development work leading to construction of an intermediate energy reactor for propulsion of a submarine. The Electric Boat Co., of Groton, Conn., is associated with General Electric Co. as the submarine builder on this project and is also serving in a similar capacity on a prototype reactor of different design which is being constructed by the Westinghouse Electric Corp. at the National Reactor Testing Station in Idaho.

During all phases of design of the West Milton project, careful attention has been given to the safety of operating personnel and off-site areas. The reactor will be housed in a steel sphere 225 feet in diameter similar to structures widely used in the chemical and petroleum industries. This special type of reactor building is being designed to provide, during preliminary test operations, protection additional to the many safety controls of the reactor itself. Negotiations are presently under way for the design and construction of the sphere. Conventional construction work at the site will be done under fixed-price contracts awarded as a result of competitive bidding.

The land-based prototype at West Milton will contribute research, development, and operating data important to design of future reactors for producing power for industrial and commercial purposes.

The Knolls Atomic Power Laboratory also is engaged in furnishing technical assistance to the plutonium production center at Hanford, Wash., which is operated by General Electric for the AEC, and to the Savannah River plant which is under construction by du Pont.

80. WHERE ARE WE GOING IN ATOMIC ENERGY?

Remarks Prepared by Gordon Dean, Chairman, United States Atomic Energy Commission for Delivery Before the Economic Club of Detroit, Mich., March 3, 1952

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Some people use the word "explosive" to describe fissionable materials, but this, too, has its limitations because the other materials we know as explosive are pallid by comparison. And then, too, fissionable material is something more than an explosive—it is also a fuel in that it can be made to produce heat slowly and in a controlled way. But it is quite unlike other fuels in that its B. t. u. content per unit of volume is millions of times greater.

But whatever we call it, our fissionable material is truly one of our greatest resources. It is valuable in war; it is valuable in peace. I don't think it would be an exaggeration to call it the greatest accumulation of wealth in the world.

Let's make no mistake about it, however: This material has been produced in the relatively large quantities in which it exists today for but one reason—it can be used in weapons. And for this same reason it is stored in the form of weapons.

If fissionable material were not useful in weapons, I am sure we would not have the great plants in which to produce it that we have today. We might have a small plant or two, but certainly not on the scale we have now or plan for the early future. I say this for two reasons:

1. As valuable as fissionable material is, its value as a fuel alone is still not as great as the cost of producing it by the methods we use today. In other words, if fissionable material were useful only as fuel, the method by which we produce it today would be uneconomical.

2. Along with this fact, there is the interesting possibility that fissionable material can be produced in combination with another useful product—electric power—thus substantially reducing costs, possibly to the point where the fissionable material could be produced at a cost commensurate with its market price for fuel use alone. In other words, there is a chance that fissionable material can be produced by a method that would be economical.

If there were no cold war, this second route would probably be the one that we would follow exclusively. But there is a cold war—and an arms race—and under the pressure of it we have taken the first route—the route of producing fissionable material in as great a quantity as possible and at high cost if necessary.

But this fact, fortunately, does not make the fissionable material we are now accumulating of any less value to us as fuel. It is valuable to us as fuel. It will always be valuable to us as fuel. And, if it is never used in weapons, it can always be taken out of the Atomic Energy Commission's stockpile of weapons and put to work for the benefit of mankind. As long as it is held for this purpose, it exists as a tremendous potential dividend on the great investment we are now making in national security.

But all this has had to do with where we are now in atomic energy. Now let's look at where we are going—or, to state it more accurately—at where we think or hope that we are going. To help tie this discussion together, I would like to talk about our objectives in terms of the stockpile of fissionable material that I have just described.

In these terms, our first objective is to make that stockpile bigger. This, essentially, is why we are engaged in the two-and-a-half-billion-dollar expansion program we now have under way. It is also why the President has said he will shortly ask the Congress to authorize another great expansion of our fissionable material production capacity that will cost about 5 billion dollars.

It is also why we have recently raised the price we pay for domestic uranium ore and why we have entered into an agreement with the Union of South Africa whereby we can purchase uranium produced there as a byproduct of gold production.

Our second objective—and this has equal priority with the first—is to develop ways by which we can translate the latent power that exists in our stockpile of fissionable materials into terms of maximum usefulness. This means the development of new weapons and better and more efficient types of weapons and methods of manufacturing them, and it explains why we have been having so many weapons tests in Eniwetok and Nevada and why there has been such a great atmosphere of urgency about them.

If we can continue to increase the military usefulness of our stockpile of fissionable material through improvements in weapons design and technology,

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we will be increasing our atomic strength just as surely as though we were to buy still more uranium ore at still higher prices, and build still more 1- to 2-billion-dollar production plants. That is what we are trying to do. We are trying to expand our production capacity as much as we can and we are trying to improve and vary our weapons designs as much as we can. We are going both routes because the Congress and the American people think it is important, and we think it is important, that we stay ahead in this atomic arms race.

We do not welcome this arms race, and we would much rather that it didn't exist. But it does exist, and as long as it goes on we think it is the hope of the free world that we stay in the lead.

We are in dead earnest about this, and we strongly believe that time is of the essence. This explains why we sometimes award a cost-plus-fixed-fee type of contract where, if time were not so important, we would rather go through the more leisurely process of inviting and considering bids and then catching up with changes in design with time-consuming contract modifications. It explains, too, why on a few occasions we have tolerated overtime practices that would be unthinkable on less urgent kinds of work. And it explains why we frequently must go back to the same contractors for similar kinds of work when we would rather give somebody new a chance to come in and learn our business.

Our third major objective is to develop a hydrogen bomb in accordance with the President's explicit directive to do so. This work, too, is related to our stockpile of fissionable material since, if explosive energy can be derived from the fusion of hydrogen, then a corresponding quantity of fissionable material can be saved. Even with the hydrogen bomb, however, our stockpile of fissionable material would remain of the utmost importance.

Our fourth major objective also has to do with that same stockpile of fissionable material. But this time the objective is a peaceful one. Specifically, it is to develop machines in which fissionable materials can be made to react slowly and produce heat that can be used in the generation of useful electric power. If the cold war were to end tomorrow, this would be our main objective, but for so long as the cold war goes on, it must rank behind the others. It is, nevertheless, an important objective on our thinking, and we are going about achieving it in two ways:

First, we are trying to gain from our military work all we can that is of value in advancing us toward our goal of producing useful power. There is much that we can put to use. A lot of it is knowledge—knowledge about reactors, about nuclear physics, about chemical processing, about the nature of radioactivity, and about materials. We are taking this knowledge and we are applying it wherever possible to the solution of our power production problems. This helps—at least in parts—to compensate for the priority we have had to assign to weapons.

The second way we are going about achieving our power goals is to bring a direct attack to bear on them—albeit an attack that must be carried on without interference to our weapons production schedules.

The nature of this attack has also been strongly influenced by the times. Our main immediate practical goal, for example, is not to build a reactor that will produce power to light a city—it is instead to build a reactor that will produce power to propel a submarine.

The reasons we are working on this submarine reactor first is because there is a clear and urgent need for an atomic-powered submarine. Reactors will run for very long periods of time without the need for refueling. They will also operate without oxygen. For submarines, therefore, where the need is for long range and the ability to remain submerged for very long intervals, atomic power plants are a natural.

And so, among reactors designed for a practical purpose, we are going after the submarine reactor first. But in doing so, we are at least building a reactor that will produce useful power, and the dividend in knowledge that we gain will have a direct and immediate application to our effort to produce commercial civilian power. As a matter of fact, it is probably very fortunate, from the peacetime point of view, that the Navy wants an atomic-powered submarine, for this gives us the incentive of working on a reactor for a real, practical purpose at a time when otherwise we would probably have to stick to research and developmental machines.

This whole question of power reactors is largely one of economics. I think practically everyone associated with the reactor phase of our program agrees that the technology has reached the point where reactors can be built to produce power. As a matter of fact, you may recall that last December one of our

reactors out in Idaho actually produced some power experimentally. That reactor isn't a real power plant by any means, but the experiment proved beyond any doubt that power can be produced from atomic power. But if we hadn't believed this all along we never would have begun work on the two submarine reactors we are now developing.

I think the best way to describe the status of our progress today is to say that reactor technology has reached the point where we can build reactors to produce power, but we cannot yet build them to produce power economically. This explains why we can build a reactor to propel a submarine—where low costs are not so important—and yet cannot build one to produce power to put on the market—where costs are controlling.

Our next big objective, then, is to move in on these costs. This involves, among other things, making our reactors as efficient as possible—that is, getting as much power as we can out of each dollar invested in the plant. This, in turn, means getting the temperatures up and devising ways of getting as much heat as possible out of the reactor and to a place where it can be put to work producing power. These are technical problems and they are the kind of problems to which we are directing our attention.

But parallel with our own attack on these problems, the program has reached the point where private industry is beginning to bring its own enterprise and initiative to bear on them. As many of you probably know, we have recently had representatives of eight companies—including the Dow Chemical Co. and Detroit-Edison Co.—inside our program for the purpose of studying the reactor development situation. These companies want to know what they can be doing with their own money to get into reactor development work with a view to producing power. Most of them have already submitted at least preliminary reports and we are now studying them. We are very hopeful that something good will come of them—for us, for the companies involved, and for the American people.

There is one clear break that atomic power development work will get because of the international situation. This stems from the high value placed on plutonium because of its usefulness in weapons. Since reactors can be made to produce both power and plutonium at the same time, this means that the income received from producing plutonium could be used to reduce the cost—and therefore the price—of the power. I think it is obvious that the higher the value of the plutonium, the lower the cost of the power can be. For so long as there is a large demand for plutonium for bombs, then, there is a chance that power can be produced at competitive prices earlier than would be the case if there were no military demand for plutonium. The industrial groups who are studying the power situation are well aware of this possibility.

Although the day of economic power from fission is not right around the corner, there are some way stations along the road that it will be very encouraging to arrive at. One we have already reached. This was the experimental production of power in Idaho. The next will be the successful operation of a submarine reactor, where cost is not a controlling factor but where the power will be used for a practical purpose. The next will be the day that power is produced at competitive prices with the aid of the weapons market for plutonium. All of these will be significant milestones, but beyond them the future of atomic power will be governed rather largely by such economic forces as the relative value of coal and oil in certain specific areas, and the relative value of atomic power for certain specific uses in different industries. Time, and only time, has the answer to these questions. All we have control over is our rate of progress in reactor technology, and this is something we are pushing as hard as we can.

What all this will mean in terms of bringing peace and prosperity and freedom to this tormented globe of ours I am not prepared to say. In my view it certainly will not set us back. To have another, completely new source of power, where fuel transportation costs will amount to virtually nothing, will obviously have a significantly desirable effect on many parts of the world and many parts of our own country. Atomic power, together with power from coal, oil, gas, and falling water, should provide us with the wherewithal to supply the energy needs of the world's growing population and our strong desire to raise steadily our standard of living.

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I have said this before, and I would like to say it here again:

"I make no apology for the priority which we have assigned in this country to building bombs. We have had to do it because to follow any other course

would be to invite war. We have in the Atomic Energy Commission figuratively been breaking our backs to stay ahead in this bomb business. And we shall stay ahead—of this you can be sure.

"But there is bound to come a time when sanity will be restored in this tormented globe of ours. It may come when the likelihood of an holocaust is dissipated. It may come only after the holocaust is over, although I am sure there is no thinking American who hopes to win permanent peace in this way. But sooner or later sanity will return, and when it does it would be a most tragic day if the strongest country in the world were not prepared.

"The people of the United States have committed to the members of the civilian Atomic Energy Comission a very heavy responsibility. And they have acquiesced as we have accumulated at great cost large stores of materials which may someday change man's entire mode of life—and which represent a wealth far greater than all of the gold stored in Fort Knox.

"Someday we shall be asked by the people of this country—and the people of the world: 'Are you ready now for the peacetime applications? Are you ready with the cures for disease, with the industrial uses of atomic energy? Are you ready with commercial power? Are you ready with all the other beneficial applications which are bound to be demonstrated?'

"When this day comes, we in the Atomic Energy Commission want to be in a position to say, 'Yes, we are ready'—and we try always to bear this fact in mind as we bend our energies to the production of weapons.

"Someone has rightly said, 'The night is darkest just before the dawn.' The night is admittedly very dark. But we must be ready for the dawn, for it will—most assuredly come."

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81. EXCERPT FROM SPEECH BY KENNETH S. PITZER, DEAN OF THE COLLEGE OF CHEMISTRY, UNIVERSITY OF CALIFORNIA, BERKELEY, MARCH 7, 1952

At this point I would like to offer some general comments on policy questions and on the effectiveness of our atomic energy effort. My direct responsibilities were in the field of basic research in the physical sciences. I will leave it to others to comment on that program; the results, where nonsecret, are in the scientific journals. I will say, that on the whole, I received excellent support from both the Commission and other governmental authorities.

I would like to discuss the areas closer to our major development objectives: weapons and power. It is easy to offer sweeping generalizations in favor of or against something. But such comments are seldom the whole story and certainly would not be in this case. The AEC is reasonably efficient by general governmental standards, but I believe we have a right to expect something special in this vital area. Consequently, I hope I can offer some critical comments without having these interpreted as a sweeping condemnation.

My comments are along the following line: Our atomic-energy team has a large roster of good players but its performance could be improved by some changes in the coaching staff. Also some of the rules under which it plays seem to slow up the game unnecessarily.

The good sound players are the men in the atomic-energy plants and laboratories. Some star performers left in 1945 and 1946 at the end of the war; but after a reorganizaiton period new leaders emerged, gained stature and experience and are now giving comparable performance to the old stars. Weapons are being produced in substantial numbers and in greatly improved models. The Los Alamos Laboratory deserves credit for an excellent performance. Both the Argonne and Oak Ridge Laboratories are bringing forth very interesting improved reactor designs as are the General Electric and Westinghouse Atomic Energy Power Laboratories. Also in the area of more basic research our own radiation laboratory at Berkeley and other groups are making remarkable progress.

However, in many cases the basic rules of procedure are not conducive to the best results. There is something wrong when Mr. David E. Lillienthal, the advocate—even the symbol—of public power, says, "The time for the first industrial applications of atomic knowledge is overdue. Let's end Government monopoly and give American competitive industry a chance." I do not agree with many of the details of Mr. Lilienthal's arguments, but I believe he is correct in pointing the finger at monopoly.

In spite of congressional investigations, monopoly tends to be a comfortable position. If unnecessary time is taken to reach a decision, there is no competitor here at home to move into the field ahead of you. If there are unnecessary men employed on a job, it's just part of the cost—there is no danger of losing money on the job. This lack of real incentive to reduce costs, tends always to leave the cost floating around at some level, not disgracefully high, but not necessarily near rock bottom. How can we ever find the true cost of atomic power if the actual costs are inflated?

Of course, part of the difficulty is the intrinsic military use of all the principal products of atomic energy at this time. But there are contracting methods which give the contractor an extra profit if he improves efficiency which could be used more widely than they are. The Congress should encourage the Commission to suggest means by which its degree of monopoly could be reduced and should then cooperate in their implementation.

However, it must be admitted that it will take some time to get away from the AEC monopoly. Can we not make more rapid progress toward both military objectives and useful atomic power in the meantime? I believe we could.

During the war the first reactors and the bombs were actually produced within about 3 years. At that time, if there was a major disagreement as to the best route to follow in a development, both routes were followed. In the more recent period the reverse has been the usual case—when disagreement arose neither route was followed until an exhaustive series of preliminary studies was completed. This might well delay the project a year or more. Such delays are actually expensive, because all sorts of costs continue during the period of indecision.

After the successful operation of the Hanford reactors, the additional task to build a power reactor was certainly no more difficult than had been the original wartime assignment. Yet it was over 6 years later when the reactor at Idaho first produced a hundred kilowatts last December.

The slowness did not arise from a lack of designs for power reactors which reputable scientists and engineers were willing to build and test. It came rather from an unwillingness of the Commission to proceed with any one of these designs until all of the advisers agreed that this was the best design.

The situation might be likened to an automobile equipped with separate brake levers for each passenger. At every road junction the driver not only had to discuss his preference of route with his riders, but he had to wait until all were convinced, because any one could stop the car. Considering that the power reactor territory is not clearly mapped, it is not surprising that more time was spent stationary than moving. We need either to remove some of the extra brakes or to shift riders to men who will reply to the driver, "Take the road that you think best and let's move ahead."

In my analogy there is one necessary passenger with a brake lever—this is the Commission itself. However, the other passengers are there by the Commission's invitation. They are a multitude of part-time advisory groups and boards. Although the motive is not stated, I presume these boards of noted experts were intended to shield the Commission itself from criticism if some project should fail. But let me give you one example of how such a board tends to operate.

A reactor is potentially explosive—like a steam boiler or a gas tank—therefore safety considerations are appropriate. The devices, analogous to safety valves on the boiler, should be installed to make reactors as safe as possible, and this must be very safe. No one questions the need of all reasonable safety features, but we have actually gone to silly extremes.

Both the Argonne and Oak Ridge Laboratories are situated on large tracts of land where isolated test sites are available. The reactor designers in the laboratories included all types of safety features in their plans. Nevertheless, it would be entirely reasonable to ask an independent committee to check these designs to see if any errors were made.

But instead of that, the committee was asked to report whether there was any hazard at all in the operation of the reactors on the sites proposed. Of course, you can always hypothesize that all safety devices fail and that some extreme form of sabotage is committed. Then one can assume the most unfavorable possibility in every subsequent part of the catastrophe.

On that basis, a gasoline tank truck has more explosive potential than a blockbuster TNT bomb and should never be allowed in a city at all. Yet, with all the accidents involving gasoline trucks, this maximum explosion has never

occurred. It would be absurd to forbid gasoline trucks to enter city streets—more moderate safety restrictions are sufficient.

No reactor has ever exploded, and we are continuously learning how to make even safer types. Still, when a committee is asked effectively to take responsibility for reactor safety without any balanced authority over mode of operation or other factors, I do not blame them for pointing out these ridiculously remote risks. Yet the report, once formally issued, led the cautious Commission to hold up the reactor projects until the vast Idaho proving ground could be procured.

The proving ground is probably a wise investment, because it makes it possible to test the most high-powered and sensitive reactors without the caution that nearby populations would necessitate. But the safer and smaller models could have been built without any significant risk on the original Argonne and Oak Ridge sites with great savings in both time and money.

I believe this decision delayed the reactor development program at least a year. The mistake was the failure to trust the laboratory directors and reactor project engineers—the very men who knew the most about the problems and the men who were really staking their reputations and lives on the safety of their designs.

The last AEC report shows sixteen of these part-time advisory committees appointed by the Commission in addition to the several statutory committees. Some of these groups are helping to get the job done but I am afraid far too many of them are actually impeding the work in spite of good intentions. These should either be abolished or shifted to report to a subordinate official who can steer their efforts in a constructive direction. There are now too many cooks tasting the broth before it is served; there are too many sources of a high level negative decision which, once rendered, is then nearly impossible to overcome.

The AEC has able and responsible men in charge of most of its projects and laboratories. The Commission should show more confidence in them. Of course, if any individuals do not merit this confidence, they can be replaced. The Commission should make the goal and the budget clear in each case and then support the group that is doing the job instead of calling upon part-time advisers and consultants to double and triple check each step.

In summary the rule changes should bring in more incentive to efficiency and cost reduction, and should give greater authority to project managers who are getting jobs done as compared to kibitzers.

This leads to my suggestion that some changes in the coaching staff would be desirable. I refer particularly to some of the most influential members of the statutory General Advisory Committee who have served continuously since the establishment of the Commission. These are able men for whom I have a very high personal regard. No doubt they served an important role during the period when new leaders were being developed in the laboratories. However I believe the proper role of the Advisory Committee has now changed and there needs to be a corresponding change in membership. We now need men who will specialize in pointing out new fields to explore rather than in double checking decisions in projects already under way.

Also, I am sorry to say that some of these Committee members of long standing seem to have remarkably little enthusiasm for the primary goals of the atomic energy program. Their recommendations on military projects are, of course, secret, and I am not at liberty to discuss these. Concerning useful power, some have spoken publicly. Dr. James B. Conant, has stated that he has little hope for useful atomic power and has predicted that in the 1960's the effort in that direction will be abandoned. Certain other members of the committee have expressed similar opinions. Certainly more constructive advice should be obtainable from men with faith and enthusiasm in the job to be done.

There are men of comparable stature who are on record as believing great new developments in atomic energy are possible. These include Dr. Harold C. Urey, the Nobel laureate, Dr. Farrington Daniels, the president elect of the American Chemical Society and Dr. Charles Thomas, ex-president of the ACS and President of Monsanto Chemical Co.

When Mr. Lilienthal had lost his enthusiasm for the Atomic Energy job he stepped aside. I am sure we will get more vigorous leadership, both on the Commission and on the advisory committees, from men who have enthusiasm for the general program than from those who do not.

I am fully aware of the difficulties which have confronted those charged with the atomic energy program in recent years. Much time had to be spent answering ill-informed or prejudiced critics. This criticism tended to make the

AEC cautious. However, the production of a force that would deter aggression in Europe has certainly been well worth while. There are equally worth-while goals ahead. I believe there is an opportunity now for a period of greater teamwork and even more rapid progress. I hope it will be realized.

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82. WHAT'S WRONG WITH THE ATOMIC-ENERGY PROGRAM

By Dr. Kenneth S. Pitzer, Former Director of Research, Atomic Energy Commission

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Question. You have been criticizing the official policy in the development of atomic energy, Dr. Pitzer, and we are interested in knowing just what you think is wrong——

Answer. I have been trying to be constructive about it. I believe that we could have made more progress and I feel there are changes to be made to improve things.

Question. Do you feel that civilian uses of atomic energy are being stunted more than is necessary now?

Answer. I don't feel that anyone is intentionally stunting them, but I do feel that there certainly are procedures being followed which are not the best for rapid development.

Question. Is that a technical matter, or an attitude of mind?

Answer. It's mainly a matter of unnecessary caution in proceeding. In other words, here is an engineer in the laboratory who has a potential power-reactor design that he thinks will work and he would like to build and test it. Of course, it must be decided whether the cost estimates are reasonable and can be afforded or not. Also it is reasonable to have some consultants check the design for technical errors. However, if it is a really new design, there will be some feature of it which someone will think may not work. Then too often the decision has been, "No, we won't build it."

Question. Is that going on?

Answer. Yes, it has happened often enough to discourage some of the best men in the reactor field. I would like to emphasize that I am not advocating greater expenditures. I believe the change should be to place the technical guidance in the hands of men with real daring and enthusiasm. Also one must avoid excessive red tape.

Question. How does cost enter into a decision on whether or not to try a new design?

Answer. I would certainly recognize that a design might be proposed which would be just too expensive and it would be properly decided that we can't afford to put that much money into it.

Question. In general, has it been a matter of money?

Answer. No. The question usually resolves itself into one group of scientists saying, "We think it will work," and another group saying, "We're not so sure—it might not work." The question then is, what do you do—do you bet on the team that believes it can accomplish the job and make it work or do you say, "No, we won't try it if there is any doubt"?

Question. How much would you be gambling in a case like that?

Answer. You may be gambling a million dollars or even several million dollars. However, the laboratory operating budgets are of that size every year. It isn't necessarily an economy to wait too long before building and testing a complete unit. May I emphasize again that it is not the over-all budget that I am complaining about.

Question. What type of power reactor would that be? A locomotive, or a plant to make power—what type of thing are people generally interested in?

Answer. Well people are interested in a great many things, and I have said that probably the atomic-powered submarine will turn out to be the first "useful" atomic power plant, because there are some very special features that make extra costs acceptable in the case of the submarine. People have not been thinking essentially in terms of what you're going to do with it, but in terms of the power plant itself.

Take the analogy of the Diesel engine. Actually, again the submarine was one of the first practical uses of the Diesel engines, but the real problem for the engineer was to develop the Diesel engine, not to develop the Diesel engine specifically and only for a submarine. In the long run, the Diesel engines that drive the locomotive, that drive the small-community electric power plant, that drive the pumping station—they are all practically the same engine. You modify them, a little one way or another.

Question. That would be true, too, of a submarine with an atomic power plant?

Answer. That's right. True, it is going to be modified in detail, but the main features of the plant will be the same whether it is in a submarine or somewhere else.

Question. Won't the actual use of an atomic power plant in a submarine bring about further developments?

Answer. That is true, and that is the reason we are all happy to see the submarine pushed as hard as possible, because 90 percent of the information you learn in designing a submarine power plant would be quite as apt to do for some other purpose.

Question. Is there some hindrance to the development of the power plant for submarines, caused by official attitudes?

Answer. No, I wouldn't say that ideas are being held back, nor that there are now any serious restrictions on the submarine program. One of the aspects to which I devoted some attention was the question of safety. An atomic power plant is somewhat analogous to a steam boiler—it could blow up. You want to put a safety valve on it and you want a good safety valve. However, what happened was that, even though excellent safety devices had been proposed and were installed, the question was raised eventually, "Is there any remaining risk?" Now you can always hypothesize that some little boy sits on the safety valve, or that sabotage occurs, or just assume it doesn't work. On that basis, you can assume, for example, that a gasoline truck in a city would leak in such a manner that an ideal mixture of gasoline and air would be formed and it would damage all the buildings for a long way. It never has happened—but this is the sort of reasoning that has gone into the basic factors on reactors.

Question. What was the result?

Answer. The result was that we went out and bought enormous acreage in Idaho and held up reactor projects which could have just as well been built on reasonably large tracts of land, say, at Oak Ridge, Tenn., or at the Argonne Laboratories out in Du Page County, Ill.

Question. You think the attitude has been too cautious?

Answer. Yes. I do. The fellow who runs the reactor—he doesn't want to blow himself up. He is going to put in the best safety devices, and the idea of assuming that all these fail is being ridiculously cautious.

Question. Who made the decision to go out there?

Answer. This was slightly before my time with the Atomic Energy Commission, but the Commissioners apparently decided to call in an outside advisory committee on the reactor's safety. I think it would have been entirely appropriate to ask this group, "Do these reactor designs have any mistakes in them? Is the designer's safety calculation right?" But essentially, instead, they were asked, "Is there any risk?" and, of course, you can always hypothesize some sort of risk. And when the Commission got a document back from this committee saying that there was this or that risk, they were in a very cautious mood and said, "We musn't go ahead on the sites that are now available."

Question. So that much time was lost?

Answer. It's hard to guess how much—maybe a year.

Question. It cost a lot of money to go out to Idaho?

Answer. It cost a good deal more. If you are building a reactor right next to your laboratory you can use your own shop and make a lot of the parts, or you can handle them by relatively simple, well-supervised contracts. If you are out somewhere else you have to bring in new general contracors, who must build their own shops and facilities.

Question. You would have to build a big project to develop this, too, wouldn't you?

Answer. Oh, there is quite an establishment out there.

Question. Did anybody question the decision at the time?

Answer. There were lots of questions raised informally, but I am not sure whether there is any documented questions that one could put one's finger on.

Question. Could you say how many people judged the safety device before an outside group was called in?

Answer. Essentially, the whole team who designed the reactor—a team of possibly 20 top scientists and engineers.

Question. In other words, it's not in the hands of one or two or three individuals?

Answer. No.

Question. Is that the only decision of this kind, or is that typical?

Answer. I would say it is somewhat typical.

Question. So that we may be going too slowly in our development?

Answer. Yes.

Question. Do you think the Russians are that cautious?

Answer. No.

Question. Their progress, therefore, may be faster?

Answer. I don't think we're getting really behind, because I think we have such greater numbers of good technical people that we can carry some extra burdens and still keep ahead.

SECURITY-RISK PROBLEM

Question. Does the same excessive caution you mention also apply to risks on the security side?

Answer. I am not so inclined to think that failure to take chances in terms of declassifying information has really held things up very seriously. There are undoubtedly places where, if certain information had been released, certain extra strength could have been applied to a program, and where hindsight has indicated that there wouldn't have been any loss at all. I believe we can maintain security and still make rapid progress.

Question. Is the military hesitant in the same way the civilians are in pushing this development?

Answer. The military have been pushing pretty hard for the development.

Question. So it is more the civilian than the military that has been hesitant?

Answer. Not 100 percent, but the tendency on the part of civilians to be too cautious has had the greater effect.

NOVEL WEAPONS ARE DELAYED

Question. Is that true, too, with regard to weapons, or does that apply just to power?

Answer. I feel freer to talk about the power end than I do the weapons end because the semiannual reports of the Commission give public information as to how reactor projects are coming along.

Question. Not in detailed terms, though—just generally?

Answer. In general terms, I have a feeling that certain weapons programs are not going as fast as they could, where they are of a very novel character. On the other hand, I think the Los Alamos Laboratory has done a bang-up job within its capacity and facilities in the regular weapons field.

Question. Is there anything going on down there that could be talked about?

Answer. Let me put it this way: I think people who have been actually on the job in Los Alamos have done an excellent job and have accomplished all that could be expected. Some additional activities have been suggested which could have been supported more vigorously by the General Advisory Committee and the Commission. I don't believe I should be more specific than this.

Question. Is the hydrogen bomb, if any, to be of any peaceable use?

Answer. The so-called thermonuclear process might conceivably have some peaceable use, although it is pretty vague.

Question. But it might be controlled?

Answer. It might, yes. I'm not even going to postulate how it might, but I never like to say that something is impossible—there have been too many people who have predicted something was impossible and within 10 years somebody did it.

Question. Is there going to be a hydrogen bomb—is that a possibility?

Answer. Well, that's getting pretty close to secrets.

Question. Do you think the decision should be to go ahead with the hydrogen bomb?

Answer. I certainly do. I don't believe that you increase your military strength by intentionally remaining in ignorance on anything. I believe the vigorous prosecution of the H-bomb program is vital to this country's military strength. All likely avenues should be explored.

Question. Are the private-utility interests holding up power developments?

Answer. No, I don't think so at all. There are the industrial study teams, with which you may be familiar. The one who spearheaded the project was Charles Thomas, of the Monsanto Chemical Co. His company, together with an electric utility or two, make up one of the teams. There are three other teams of similar character, that is, an industrial or chemical company, together with the utilities in each case. These study groups are essentially trying to see whether one could make, economically, power and plutonium in a combined reactor job. I think they represent a very desirable thing because they give the opportunity of getting atomic energy out of the Government-monopoly stage into private business, besides getting some variety of competition.

Question. You have indicated that business must have a larger part—how and where?

Answer. The first fact, of course, is that the present operations are all under contract to industry but they are almost all cost-plus contracts, which is not really getting industry into it. I think this very proposal would be a good one, if it could be worked out, whereby private industry would build and operate the reactors and the Commission would furnish the uranium and buy the plutonium at an agreed-upon price, and the industry would be free to sell the power and sell any other byproducts in their own way.

Question. Is cost known enough in advance to make such a contract?

Answer. The Commission knows what it costs to make plutonium at Hanford, without power. They ought to be willing to pay the same price for it, and if somebody can make power and make a profit, then it's all to the good.

Question. Industry might build many plants instead of one or two big ones?

Answer. I would let industry select their own locations.

Question. How soon could they do that, technically? Is it possible now?

Answer. I think we are getting close to the stage where it is possible.

FINANCING BY INDUSTRY

Question. Is industry in favor of it?

Answer. The fact that industry is putting its own money into these study groups indicates that it is in favor of it.

Question. And there is no problem in financing? The financing is not too great for industry?

Answer. The cost could be of the same general magnitude as present power stations. Industry is financing a lot of steam power plants. If they could see their way clear in terms of operating profits there is no reason why they shouldn't finance nuclear power plants.

Question. Nuclear power plants are no more expensive?

Answer. No; nuclear power plants will be more expensive at first. That's why the Commission would have to guarantee that they would pay a fair price for the plutonium over a period of years sufficient to amortize the cost of the plant.

What the Government would have to do is promise to buy the plutonium, that is, the weapons material, over a reasonable period of time.

Question. Would atomic development go along faster if such a program were evolved?

Answer. That's asking for a prediction, but I would guess it would.

Question. Is it possible by going ahead on a cost-plus contract—and thus determining design and cost, before you let wider contracts—the Government might end up by buying its plutonium a great deal cheaper?

Answer. I think it's a good idea for the Commission to have one of its own organizations, say the Argonne Laboratories, make a design of the same sort of unit. But unless they feel pretty sure their design is better, I think it is desirable to get atomic energy into the realm of ordinary industrial operation, and out of the special category in which it has been.

SAFETY VERSUS DEVELOPMENT

Question. Is the safety factor holding up wide industrial development?

Answer. Well, there have been no firm propositions to actually go ahead with it, so that I can't answer that. Should the Commission put as stringent safety

requirements on in the future as they did 2 or 3 years ago, I think it would hold the thing up very seriously. I trust they won't do that.

Question. But atomic energy does offer a real source of power that probably would be a large part of the picture?

Answer. I would say in the near future it should be thought of as either a specialty power or a byproduct power. By specialty power I mean things like submarines and by byproduct power I mean the combined plutonium and power production. Whether it ever becomes a general source of electric power in its own right is in the distant future, which I can't see very clearly. Take the Diesel engine. The Diesel engine has never become a general source of power in very large units. But it certainly has been a valuable component of our industrial development.

Question. Will it be a cheaper power in the long run?

Answer. That is intrinsic in the answer I was just giving. I can't see that it is necessarily ever going to become the cheapest power in terms of large lots, but the fuel consumption per horsepower-hour is essentially zero—it is far less than coal or oil or anything else. It will have a great advantage where you have to haul the fuel, or where the vehicle has to carry the fuel with it, if the distances are large. In other words, where it is very expensive to haul fuel over long distances to certain areas, atomic power would have an advantage as compared to areas that are near major coal fields, and so on. Likewise, in military vehicles where a cruising range can be essentially independent of the size of the fuel tank, it would be a major factor.

Question. Then it would be just as feasible to put in a battleship as a submarine?

Answer. Oh, yes.

Question. Or probably a passenger ship?

Answer. Except that a passenger ship wants to stop for passengers anyway and might as well fill its fuel tanks at the same time, whereas a battleship or submarine in hostile waters doesn't want to have to stop.

Question. They might use the fuel space, though?

Answer. Yes, though this remains to be seen. You would have to put a radiation shield around the reactor, and it's not clear whether there is a net saving of space.

Question. Are there raw materials enough for all of those things?

Answer. That is again something you can't say for sure, but the harder we work at discovering raw material the more we find.

ATOMS FOR AUTOS?

Question. Do you visualize the possibility of atomic-powered automobiles or atomic-heated homes?

Answer. The scientific concept of a critical mass or critical size has been discussed quite a little. It means essentially that there is an intrinsic minimum size below which the thing just won't work at all. This almost certainly means that individual home or individual auto applications are too small to be interesting.

Question. Is that true of the locomotive in the railroads?

Answer. I wouldn't be certain of that. I don't think the locomotives are just around the corner, but I would hesitate to predict that they would never be possible.

Question. How about trucks on the highway?

Answer. They would be less likely than locomotives.

Question. Do you feel that getting atomic energy out in the form of power plants would speed the day when we would have these other applications?

Answer. Yes. The knowledge of one type of atomic engine will find application to other types. Also it will help to develop a larger group of atomic engineers—people with ideas about how atomic energy might apply to their particular problems.

Question. And you don't think we would be giving away secrets if we went into that kind of program?

Answer. I think we should keep the legitimate importance of secrecy in mind at all times, but I think we can go quite a way in this direction without any danger of giving away an important military secret.

Question. Is there a doubt that the Russians know how to do many of these things?

Answer. There doesn't seem to be much doubt that they know a good fraction of it.

Question. Have we been too secretive, do you think?

Answer. I said before I was not inclined to feel that secrecy was the major difficulty. It's been a tough problem and I think it has been handled in a fairly common-sense fashion, although some decisions might have been made a little sooner.

Question. Are there ways in which business can be worked into the atomic-energy program besides the one you suggested?

Answer. It is difficult to say, but if we could get these by-product materials, radioisotopes, out in plain, ordinary technical commerce, such that anybody who wanted some could go down to the nearest supplier and buy them with no questions asked, I think we might get a lot wider industrial experimentation into their possible use. Of course, any user would be subject to the safety regulations of his State department of public health. I think it is just about now becoming a feasible thing to do.

What we had to do was to educate the public-health authorities in what radioactivity is. This took a certain length of time. Some States are further along than others. But most doctors now understand something about the business. They knew about X-rays long before. Other technical people are becoming reasonably well aware of radioactivity also. The time is drawing near when the special regulations of the Atomic Energy Commission could well be dropped.

Question. Do you think that this overly cautious attitude might be changed if the Atomic Energy Commission were made up of scientists rather than nonscientists?

Answer. I think that the nonscientist on the Atomic Energy Commission tends to be more cautious because he doesn't really understand the technical problems he is dealing with. I would rather use the term "nontechnical" there. I think engineers are just as competent to handle these things, really, as scientists because particularly in the atomic-power field it is not the physics of a reactor that's holding us up today, it's the chemistry, the chemical engineering, the mechanical engineering, the metallurgy—these are the things that are really holding us up on the technical side.

Question. So if you had men who had a better understanding of the technical problems involved you might get a more liberal approach?

Answer. I think so, although the man's general attitude is just as important.

WHERE THE MONEY IS GOING

Question. We are putting vast quantities of money into this program—do you think we're getting our money's worth? Is there any way the public can measure that?

Answer. The biggest quantities of money are going into the atomic weapons and the necessary preliminary steps in making atomic weapons.

Question. Do we need plants as large?

Answer. A person on the inside can always see places where he thinks things could be done cheaper. On the other hand, I would not make any complaint that they're not being done reasonably well. The military is the agency that ought to decide, in terms of cost, what fraction of what the country can afford for military affairs ought to be expended for atomic weapons as compared to other kinds of weapons. As far as I know their decisions are as sensible as they can be.

Question. So when we spend these billions we probably are getting our money's worth—at least, the military must figure they are?

Answer. It is their judgment to weigh atomic weapons as compared to other kinds of weapons and decide what fraction of the money ought to go there.

BRITAIN'S PROGRAM

Question. Some people are saying that Britain with much less expenditure is going to get about what we are getting with our vast effort. Is that so?

Answer. Oh, no. The British are going to learn about atomic energy, including atomic weapons, but they are not going to have anything like the production capacity in terms of numbers of units that we have. The Canadians are not actually making weapons at all.

Question. Are the British ahead of us in the development of peacetime uses for atomic energy?

Answer. I don't know the answer to that. I would not think that they were ahead of us. On the other hand they haven't been putting in anywhere near the amount of effort in either money or man-hours that we have. Also their designs are bolder than ours in some respects.

Question. The results look more dramatic though—they are heating a plant by atomic energy, aren't they?

Answer. Yes, but that is somewhat superficial. We could have done the same thing at Oak Ridge with the reactor there, years earlier. Oak Ridge had plenty of coal. The British probably had a more practical reason for doing it.

Question. Could you give us a quick outline of how an atomic power plant will work?

Answer. The atomic power plant consists of an array of fissionable material, which is the fuel, and this array is usually surrounded by a moderator, which is the material that slows down the neutrons when they are released. It then reacts of its own accord: that is, certain fuel atoms fly apart; the released neutrons go over into other atoms; these atoms also explode; and this continues under control. The only essential difference between the Hanford reactor, which yields only plutonium, and a power reactor, is that the power reactor has to run hot so that the heat can be withdrawn at a high temperature. Then, through a steam engine or most any other kind of thermodynamic engine, it can be converted into power. There are differences also in the exact types of fuel used. But in principle it's the same thing; that is, it is a unit which takes the place of the firebox in the boiler—it takes the place of the furnace in some other type of power plant.

The rest of the power plant is more or less the same as it would have been in other cases. It could be a gas turbine or a steam turbine, or some other type of thermodynamic engine.

Question. Is it theoretically possible that we will ever be able to get electrical energy out of a reactor without going through the intermediate business of heat exchanges?

Answer. It is possible in principle. I don't see any short-range practical likelihood. It is still possible in principle to extract more electrical energy by putting coal into some type of electrical cell than it is by burning it in a steam engine, but although this has been known for probably 50 years or more, it hasn't proven practical. I am afraid the same situation applies to atomic energy.

Question. Are these temperatures so high that you have to use molten metal?

Answer. No, the temperatures are optional. We are now working at just a very slight increase in temperature. There is a fundamental principle in thermodynamics which says the higher the temperature goes the more efficient your engine is, so that it is desirable to make it as high as possible. But the only thing you lose by leaving it a little lower is the few percent of efficiency, so that you don't have to go to any higher temperatures than are now used in steam-turbine plants.

ATOMIC SUBMARINE'S TALENTS

Question. But going first to an engine for a submarine—rather than for an airplane or a battleship——

Answer. The submarine has one extra factor, and that is that a Diesel engine consumes air in the intake of the engine when it operates. Therefore, if you operate a Diesel engine submerged you promptly use up all the air in the submarine.

An atomic engine would not use up the air. Now, once you get to the surface, nobody cares about that because there is all the air in the world to be had, but below the surface you might be able to store air for human breathing for a certain period of time, but not for an engine, too.

Question. In other words, you could stay submerged for a long time?

Answer. So far as the engine is concerned, you could stay submerged indefinitely. It would be a matter of what the air supply for the crew would need to be.

Question. Does atomic energy just keep on coming? Doesn't it ever stop?

Answer. Yes, but the point is you get a few million times as much energy per pound of fuel as you get out of an ordinary chemical fuel—coal, oil, and so on. And the net result is that when you divide the quantity by something over a million it becomes so small that it is practically nothing.

Question. You could run a battleship on a pound almost indefinitely then?
Answer. That's the idea. In other words, it's pounds instead of tons.
Question. Is the atomic energy industry going to go on growing?
Answer. Yes; I think it will.

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83. WORLD POWER RESOURCES

By Prof. S. Devons

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Anyone who has lived in this country during the past decade is familiar with the recurrent crises that arise from the short supply of some basic commodity necessary for the maintenance of the standard and pattern of living in this community. Shortages for example in raw materials for industry, in food or feeding stuffs, in fuel or in generated electric power, are all too familiar features of the present time. In a limited region such as our own country, and over a limited period of time such as the next year or two, the disparity between the supply and demand which engenders such a crisis is usually dismally obvious; and it is also not too difficult to estimate with fair accuracy the restriction in demand or improvement in supply that would be necessary to establish equilibrium between the two quantities in the proximate future. That this is possible is due to the fact that some previously established equilibrium which has become accepted in a particular time and place as the normal state of affairs may be upset by some specific and relatively abrupt changes; and one can picture the introduction of specific antidotes or compensations which might restore equilibrium in such a manner and in sufficiently short a time that the broad features on which the equilibrium is based remain unchanged. For example, one might deal in this circumscribed way with the food shortage that followed the recent World War and the partial restoration of the status quo ante by the resumption of normal agricultural activity; or the present-day shortage of industrial metals could be attributed to the demands of military preparations, and would certainly be alleviated, if these were to become unnecessary on the present scale.

When, however, one attempts to form a picture of the relative magnitudes of supply and demand for some basic commodity that is not only world-wide in its scope but includes more than the immediate past and future, one encounters difficulties of a different order from those which one meets in dealing with the limited situation. If we ask the questions: Are the world resources of power and energy available to man sufficient to meet his needs? Are they likely to suffice in the future—not next year, but 10, 20, or 50 years hence? We can readily appreciate the difficulties and great labor involved in making a sufficiently wide and comprehensive statistical survey of the many forms in which power is or might be produced, and the still greater diversity of ways in which it is consumed. But what is perhaps not so obvious is the far greater difficulty of formulating such questions in a significant manner. In the first place, one cannot estimate a man's basic requirements of power, even with the limited precision with which one can determine, say, the food necessary to maintain bodily health. The former vary far more widely than the latter with the level and pattern of civilization to which the requirements refer. Indeed, one can point to some highly developed past civilizations in which the utilization of controlled power was quite negligible compared with that of complex, industrialized communities of today. And for these latter it is by no means an easy matter to establish the nature of the correlation between the level of power production and the degree of civilization. One might then ask what are man's needs or demands, or any other measure of his appetite for power, in relation to a particular type, as well as a particular level, of civilization. In this form the question takes us much nearer to a problem of real significance, but it also stimulates inquiry into the extent to which the availability of power determines the pattern of civilization, or the style of life determines the basic need for power.

If we were to adopt a limited, and essentially oversimplified, statistical viewpoint, we would have first to assess the rate at which the world's resources of fuel and power have been developed and exploited, and the manner in which the power made available has been consumed. We must also estimate, albeit with some uncertainty, the sizes of the reservoirs and primary sources from which the power has been derived, and to what extent such sources will be available in

the future. If we further attempt an assessment of such factors as the probable increase in population, the technical developments in the exploitation and efficiency of utilization of power, the use of resources now known but as yet unexploited, and of the probable increase in the demand for power arising from the spread and intensification of industrialization and mechanization, one might be able to reach a conclusion as to whether the potential sources of power are sufficient, or for how long they would suffice, to maintain the particular type and degree of civilization with which we are familiar. But such a broad inquiry would, even apart from the inherent inaccuracy in the assessment of the factors mentioned, lead to conclusions of only illusory significance. For in trying to establish a balance sheet between the supply and demand for power, there are many factors on both sides of the balance which are interdependent, and some which need wider considerations outside the scope of our statistical survey. For example it is very questionable whether one should assume the change in world population to be a factor only determining the demand for fuel, and not itself partly determined by the availability of this commodity. Likewise the extent of technological development throughout the world is not only a factor determining the demand, but is also, and in a way more difficult to assess, a factor governing the rate and manner in which new supplies might be developed. And overshadowing such complexities are the still broader issues. Is any particular pattern of social and technical development, such as the present one, a possibly stable one? That is to say, can we extrapolate from the present to a future state of affairs with the neglect of any possible, even probable, major change? Such questions raise great issues whose discussion would take us far beyond the scope of limited inquiry; but they are directly, intimately related to our problem, and particularly to its formulation. One would hardly attach great significance to an estimate of the world's future requirements of power which pertained to a particular pattern of social development that one regarded as neither permanent nor stable; that might, in fact, by its very nature, indicate the inevitability of fundamental change. Moreover the distribution and utilization of power resources, with the present "random" scattered and violently uneven geographical distribution and degree of exploitation, might be major factors in determining such instability and change. And if the demand for power resources might contribute to the motive for such changes, their possession provides the instrument: there would be nothing novel in the world's resources of fuel, as of other materials, being expended in a struggle for their possession. If then we are to examine the relation between the world's supply and consumption of fuel and power, we must closely circumscribe our investigation, on the one hand lest we are led too far from our immediate problem into consideration of many imponderables of our civilization, or on the other lest we attach too much significance to a limited examination of the more directly involved and more readily measurable factors.

In the present article we intend to give a brief survey of the major primary sources of power that are of significance today, together with some indication of their geographical distribution, and of the extent of the reservoirs on which they are based. The discussion of the purposes for which power is used, the efficiency of utilization, and the possible development of new primary sources will be left to later articles. It is not appropriate for a discursive account such as this, to be burdened with numerous references to sources of information, particularly as such a procedure would imply a degree of accuracy and authority to which the writer does not pretend. Nevertheless, an attempt has been made to obtain the most reliable information and estimates, and particular mention should be made of the publications made in connection with the recent world power conferences for detailed information, and the Thomas Hawksley Lectures of the Institution of Mechanical Engineers for excellent surveys.[1]

PRIMARY SOURCES AND TYPES OF POWER

There are two broad categories into which most of the primary sources of power may be placed. The first of these represents all those actual or potential sources of power which are attributable to, and maintained by, the continuous flow of energy to the earth from the sun. For our purposes we can regard this energy flow as permanent. It is manifest in many forms; the earth's animal and vegetable life, the power of the winds, rains, and rivers and in general the main-

[1] In particular those of 1940 (by Sir A. Edgerton) and 1949 (by A. Parker).

tenance of a temperature and an atmosphere at the surface of the earth which makes life possible, and in some places even comfortable. The second category comprises all the different forms of power derived from the store of fuel contained in the earth's crust. Up to the present the only part of this that has been utilized by man on an appreciable scale is the store of "fossil" fuels—coal, oil, peat, etc., and the associated gases—a store of energy derived from the action of the sun over millions of years, but only in the past few decades seriously exploited by man. Apart from this store of chemical energy, there are other ingredients of the earth's crust, such as uranium and thorium, which provide potential, and recently realized, stores of nuclear energy. Characteristic of all the sources of power in this second category is their limited extent, and the fact that once used up they cannot be replaced, or more precisely, their rate of replacement, if any, is negligible compared with the prodigious rate of consumption.

There are some potential, and actual, sources of power that do not fall clearly into either category. Wood fuel, for example, although in principle an indirect means of storing the sun's radiant energy, is not strictly stored fuel in the same sense as fossil fuels, since wood consumed could be replaced, virtually continuously, by forestation. However, the process is not strictly a continuous one; replenishment is not made immediately, sometimes not at all. To take another quite different example, the earth's internal store of energy, manifest by such phenomena as volcanic activity, hot springs, etc., is of uncertain origin and extent. Although at present untapped, it presents great possibilities; it should probably be placed somewhere intermediate between the practically unlimited supply from the sun and finite supplies from fossil fuels.

In order to appreciate the significance of the particular sources of power which we shall discuss in due course, we shall firstly indicate the magnitude of the primary source of continuous power, the sun. For this purpose we use some convenient units of power and energy. Since coal is today still the most important single source of man-controlled power, it is convenient to take as the unit, the energy that can be obtained from 1 ton of coal, utilized in the most efficient manner possible. This is roughly equivalent to a power source of 1 kilowatt (a single electric fire or a machine of just over 1 horsepower) maintained continuously for 1 year, or about 9,000 kilowatt-hours; 1 kilowatt-year.[2] In practice this ideal efficiency of coal is not realized (a figure of 20 percent efficiency represents a rough average for all purposes), but for the moment this need not concern us. It is also important, in taking on over-all view of power resources, to realize that it is not power or energy itself that is utilized but only its availability. A primary source of power provides a certain amount of high-grade energy available for controlled use; after utilization the amount of energy appears in a degraded form, when it is not possible to utilize much of the energy further. For example, electric power used to drive a piece of machinery eventually appears largely as frictional heat in various parts of the machine, but this heat, although it may represent nearly as much energy as that originally supplied, does not usually offer an appreciable supply of controlled or available power. The energy from the sun which reaches the earth provides an example on a large scale of this successive degradation of a primary source of high grade energy.

The part of the sun's energy reaching the earth corresponds to a constant power of about 250 million million kilowatts. About half of this is reflected directly back into space; the remainder interacts with the earth's atmosphere and passes through many stages of degradation before it is finally reduced to the ordinary warmth of the earth's surface and reradiated back into space. In both its original form, as sunlight, and its many later manifestations, winds, rains, rivers, plant life, etc., this energy represents a possible permanent source, but with each stage of degradation there is a corresponding reduction in the available amount of power. In its primary high-grade form, sunlight, the amount of available power is enormous—equivalent to an annual supply of coal of about 100,000 tons for each of the earth's inhabitants. This is to be compared with a mere 1 ton per annum which is the average present-day consumption, per head, of all forms of man-controlled power. What is perhaps so remarkable about this comparison is that this tiny amount of controlled power, apparently so insignificant in relation to the radiation from the sun which determines so predominantly the forms of life on the earth, can, by its use or abuse, affect not only

[2] Abbreviations: Kilowatt, kw.; kilowatt-hour, kw.-hr., are used in the tables. A million kilowatts is written 10^6 kw.; a million million kilowatts, 10^{12} kw.

the pattern but the whole scale of human activity, and in turn of all types of life on the earth's surface.

WATER, WIND, ETC.

About one-third of the solar energy reaching the earth is spent in evaporating the waters of the ocean, and although most of this energy appears as that of rain this latter is not easily utilized on account of the very large area over which the available energy is spread. Only when part of the energy of rain, falling over the large area of a river basin, is canalized into a sufficiently powerful stream does it become practicable to extract the energy at a single place by means ranging from the primitive water wheel to a modern hydroelectric installation. Only the latter are significant on a world scale today, and their extent is still growing rapidly. The installed hydroelectric power has more than doubled in the past 25 years (see table 1); today the output of hydroelectric power is equivalent to about 7 percent of the total controlled power from all sources. The potential amount is about 20 times this, and if realized would correspond to an amount of power equal to 1½ times that obtained from all sources today. There are however, limitations in the use of hydroelectric power which these simple numerical-calculations do not reveal. If we are to consider the full utilization of all potential sources of hydroelectric power then we are eliminating any choice in their geographical location, so that power may be produced at a place, and at a time, other than where and when required. The technical problems of long-distance transmission are no doubt soluble (indeed it is partly developments in this branch of electrical engineering which have so enhanced the importance of hydroelectric power), but full utilization of resources would imply a degree of world-wide cooperation which, today, it would be rash to assume. The problem of storage is more serious than that of transmission. Electrical energy cannot be stored on a really large scale, so that apart from the limited possibilities of controlling the flow of water, hydroelectric power must be consumed as produced, and the supply is thus subject to local geographical and climatic factors which in many cases show strong seasonal variations. These may show very little correlation with the fluctuation in demand and the normal practice is to complement hydroelectric power with that from fuel-burning stations. If hydroelectricity were then to replace fuel on a large scale it would probably be necessary to adapt consumption, particularly large-scale industrial consumption, more readily to meet the variations in supply. This tendency exists at the present time but only to a slight degree, since even in North America, which produces about 40 percent of the world's hydroelectric power, only about one-third the total electricity generated is from hydroelectric installations. The potential development of power on the African Continent might produce a very different situation. In this case we have a large land area with meager deposits of stored fuel but very large potential water power—about two-fifths of the world's potential. At the present production there of power of all kinds is on a minute scale.

TABLE I.—*Water power*

(1) Geographical area	(2) Installed capacity (10^6 kw.)		(3) Estimated potential capacity (10^6 kw.)	(4) Output in 1948 (10^9 kw.-hr.)	(5) Output per head per annum (kw.-hr.)	(6) [1] Potential output per head per annum (kw.-hr.)	(7) [2] Coal equivalent of (6) tons per head per annum
	1927	1948					
Great Britain	0.2	0.3	2	1.2	25	100	0.05
Europe	8	26	150	110	200	1,400	0.7
North America	12	27	190	130	650	4,000	2
South America	0.5	2	150	9	90	7,000	3.5
Asia	2	9	340	40	33	1,200	0.6
Africa		0.3	600	1	6	16,000	8
Oceania		1	45	3	250	18,000	9
World	23	65	1,475	300	130	2,800	1

[1] Estimated on basis of present population. Population in millions: World, 2,300; Europe, 520; North America, 200; South America, 100; Asia, 1,250; Africa, 170; Oceania, 12.
[2] Assuming 20 percent efficiency for coal utilization.

Little more than a century ago wind power played an important role in agriculture and navigation. With the advent of other sources of power, wind power now plays an insignificant role, although the total power of this sort available is enormous—about 3 percent of the solar energy. If a minute fraction of this were harnessed it would be possible to dispense with all other fuels. But as in the case of rain, the main obstacle to efficient utilization is the large area over which the available power is spread. In addition there is the problem of storage in an acute form, and the heavy cost of capital equipment. Nevertheless the limited, and decreasing, availability of stored fuels is causing attention to be directed once again to the design of efficient wind-power generators. Other types of atmospheric disturbance, such as lightning, although representing appreciable amounts of power, are too erratic and difficult to exploit to be considered as significant sources of controlled power.

PHOTOSYNTHESIS, WOOD FUEL

Almost all the sunlight falling on grassland or wooded areas is absorbed in warming the ground and evaporating moisture, but a minute fraction, about 0.05 percent, is used up in the photosynthesis of carbon dioxide and water, thereby converting solar energy into an intermediate form of available, chemical energy. The process is the primary stage in the utilization of solar energy by all animal and vegetable life, including the food required to sustain human life and activities. Despite the low (technical) efficiency of photosynthesis the potential amount of energy that is stored in this way is very large, much larger, for example, than the energy content of the food consumed by man; about 10,000 million tons of coal equivalent per annum, as compared with some 300 million tons of coal equivalent per annum for the calorific content of food. Of course when one remembers the many phases through which some of this primary energy of photosynthesis passes before being available as food, and the fact that the larger part of the animal and vegetable life of the earth is not related to the food requirements of man, it is not surprising that only 3 percent of the energy stored by photosynthesis is utilized for food.

Considered as a machine for producing mechanical work which might be performed by other agencies, man is not very efficient. Apart from the loss of available energy in the many stages by which food is produced from sunlight, the actual work produced by man represents only a small fraction of energy content of the food he eats. About 5 percent efficiency for some half of the population gives, as a rough order of magnitude, some 35 million tons equivalent of coal for the whole of human labor, i. e. only one-sixteenth of a ton for each member of the world's population. From this—probably liberal—estimate of the amount of replaceable mechanical labor performed by man, it is clear that as compared with the controlled energy derived from other sources this labor is not very significant on a world scale. Even if the work performed by other beasts of burden is included, the total of animal and human labor is only a few percent of the total controlled energy. However, there are still many parts of the world where animal and human effort represent the major part of power at man's disposal.

The other means of utilization of photosynthesis for fuel on an appreciable scale is wood. About 50,000 million cubic feet of wood is felled annually. At a guess, half of this is used as fuel, producing energy equivalent to about 200 million tons of coal, or about one-tenth of the total power produced. The potential amount of wood-fuel that might be obtained from accessible forests is some three times greater, but is not uniformly distributed over the earth. Outside the U. S. S. R., for which no figures are available, about one-half the remaining resources are in the North American Continent.

Apart from wood, many other types of animal and vegetable matter are burnt to generate heat or mechanical power. The magnitude of such sources is probably insignificant in relation to other types of power, and in many cases the products burnt are local waste, such as wood shavings, sewage, etc., for which no better use can be found. There are instances, however, where, in the absence of anything better, material such as animal waste is burnt for fuel, material whose value would be much greater if used for other purposes (e. g., animal manure).

COAL, PEAT

At the present time coal provides more power annually than any other single source. Moreover its significance is not limited to the power it produces but

extends to the many byproducts and processes through which it plays an important role in chemical and metallurgical technology. It occurs in many forms—anthracite, bituminous coal, brown coal, and lignite—in descending order of calorific value, but to avoid more detail than is here relevant, we shall not here differentiate between different types. We deal with over-all quantities representing the equivalent amount of bituminous coal. In considering the power obtainable from coal we have taken into account the limited efficiency with which coal can be utilized to produce mechanical and electrical power or heat. This efficiency varies very much according to the nature of the process of utilization, but a figure of 20 percent for the average, which we have mentioned before, will indicate the correct order of magnitude at present. Coal, like other fuels and sources of power, is very unevenly distributed over the earth's surface, and different deposits are in different states of exhaustion. Moreover it is a bulky fuel and expensive to transport over large distances. Consequently most industrial processes using coal in large quantities are based near to the deposits. Very roughly then coal is consumed where it is produced. In table II, which shows the geographical distribution of resources and production, no indication is given of the amount consumed as opposed to that produced, since these are nearly the same for the large areas considered. In any case the transportation from one area to another does not affect the world picture as a whole, except insofar as transport itself involves a certain consumption.

The last column of table II indicates the time that present estimated reserves will last at the present rate of extraction. Such figures are indications only, since apart from possible changes in the consumption, it must be remembered that coal may become increasingly difficult to extract as the reserves become depleted. On the other hand the figure for reserves represents the amounts at depths which are now considered feasible for mining. Future technical developments may lead to significant changes in this respect. In addition, although the figures for Europe and America are fairly accurately known, those for some other parts of the world, particularly China and the U. S. S. R., are little more than conjectures, and although this uncertainty is not likely to affect the global picture seriously, it might be quite significant for those particular areas.

TABLE II.—*Coal*

(1) Geographical area	(2) Proved reserves	(3) Probable reserves	(4) Annual consumption [1]			(5) Consumption per head per annum	(6) Expected duration
			1927–38	1939–44	1945–47	1927–47	
	10^9 tons	*10^9 tons*	*10^6 tons*	*10^6 tons*	*10^6 tons*	*Tons*	*Years*
Great Britain	20	170	230.0	210	195	4.5	750
Europe	580	1,700	750.0	900?	650	1.4	2,800
North America	55	2,700	440.0	540	590	2.8	5,000
South America	2	3	2.5	4	4	.04	750
Asia	11	1,100	90.0	130	70	.08	11,000
Africa	9	200	14.0	20	26	.12	10,000
Oceania	7	40	14.0	18	20	1.5	2,700
World	660	6,000	1,300.0	1,600	1,400	0.64	4,600

[1] That is amount produced. Export neglected.

Despite the enormous differences in the consumption per head in different parts of the world, the world's consumption of coal as a whole has stayed surprisingly constant for the past half-century at around 1,500 million tons of coal per annum (at present ⅔ ton average per head of population). This feature is in marked contrast with other sources of controlled power, oil, and hydro-electricity, whose consumption has risen so rapidly in the past few decades. It is partly these alternative sources of power, and partly the increased efficiency with which coal is employed, that have made possible the recent great increases in the amounts of mechanical and electrical power consumed, without a corresponding increase in the consumption of coal.

As compared with all types of coal, the amount of peat consumed annually represents a power source of less than 1 percent of that of coal, and the relative magnitude of the world reserves is probably of the same order. Its significance is restricted to localities where other fuels are scarce.

The over-all situation with regard to solid fuel appears to be that there is sufficient at the present rate of consumption for hundreds or even thousands of years. Even if we were to assume a rate of consumption per head throughout the world as high as that in the United States of America, whose rate has reached the apparently stable level characteristic of a large highly developed economy, the world's resources as now estimated would still suffice for many centuries. However, there are some geographical areas (e. g., South America) where the local resources would not maintain even a much more modest rate of consumption for very long.

OIL, NATURAL GAS

The unique features of oil as a fuel are the relative ease with which it can be extracted from the earth and transported over large distances and its suitability, in different forms, for all kinds of vehicles from the smallest to the largest. The realization of its significance has occurred relatively late in the history of industrial development, after the general pattern of population had taken shape. Consequently the very uneven distribution of oil relative to the distribution of population throughout the world appears most pronounced, and the ease with which oil is transported minimizes any tendency for industry and popu'ation to concentrate near the sources. In considering the figures in table III then, we must point out the indicated production refers only to the rate of exhaustion of local reserves, and does not necessarily bear much relation to the consumption in a particular area. The United States of America, however, is the outstanding consumer and producer, using and providing about two-thirds of the world's total.

TABLE III.—*Oil*

(1) Geographical area	(2) Reserves, conservative	(3) Reserves, optimistic	(4) Annual production			(5)	(6)
			1927–32	1933–38	1939–44	Approximate 1949	Possible duration (3)+(5)
	10^6 tons	*10^6 tons*	*10^6 tons*	*10^6 tons*	*10^6 tons*	*10^6 tons*	*Years*
Great Britain	0.7	1.1	(1)	(1)	(1)		
Europe	950.0	1,300.0	23	35	38	45	28
North America	3,700.0	4,200.0	127	153	202	285	15
South America	1,400.0	1,750.0	24	31	39	77	23
Asia (Middle East)	3,600.0	5,600.0	6	11	16	47	120
Asia (Far East)	200.0	300.0	6	9	8	10	30
Africa	12.0	14.0			1	1	14
World	10,000.0	13,000.0	185	240	302	480	27

[1] Negligible.

The figures for reserves can only be considered as very tentative, and future estimates may well exceed the limits given. Between 1937 and 1948 the estimated known reserve has increased fourfold, and this despite the immense consumption in the intervening years, but it is unlikely that tendency will persist to such an extent since the rate of consumption is still rising and the regions left to be prospected, diminishing. It is also possible that future technical developments will permit fuller extraction of oil from the layers of rock in which it occurs but it is unlikely that this will lead to any great increase in known reserves. Moreover there is a possibility of much greater increase in consumption than even the figures in table III suggest. Oil is all too readily extracted from the earth, the machines which use it, both military and civil, are produced in vast numbers, and even in primitive countries with negligible industrialization, large amounts of oil may be used for transport and agriculture. The rate at which it can be refined and processed may provide some

check on the rate at which reserves are dissipated, but this is hardly likely to prevent future consumption being on a much larger scale than that of today.

Apart from oil proper there are very large deposits of oil shale from which oil may be obtained by distillation. The reserves of oil in this form have been estimated, probably conservatively, at twice those of oil proper, and some estimates put the figure as much as six times larger. However, the process of extracting oil from shale is relatively difficult, and many of the deposits may not be workable on an economic basis. The present rate of exploitation is almost negligible.

Associated with all deposits of oil are combustible gases (mainly methane) and these, according to recent estimates contain on the average about 40 percent as much energy as the oil with which they are found. Natural gas is not so easily transported and distributed as oil itself and probably for this reason much is allowed to go to waste. Even so the amount used, chiefly in the United States of America for domestic and industrial purposes, is equivalent to about 100 million tons of oil annually, or one-fifth the rate of consumption of oil.

SUMMARY OF PRESENT RESOURCES AND CONSUMPTION

We have now indicated the main sources of power utilized at the present day. In table IV we summarize the position for fuels of different kinds, and in table V the geographical distribution of total power resources of present-day types.

TABLE IV.—*World power resources*

(*a*) CONSUMABLE FUELS

	Probable reserves (10^9 tons coal equivalent)	Annual consumption (10^6 tons coal equivalent)	Annual consumption per head (tons coal equivalent)	Reserves ÷ consumption (years)
Coal, lignite, etc.	6,000	1,400	0.6	4,500
Peat	60	8.5	.004	7,000
Petroleum	19	700	.3	27
Natural gas	8	150	.07	23
Oil in shale	33	.6	.0003	55,000
Total	6,120	2,260	1	2,700

(*b*) REPLACEABLE POWER

	Present annual amount (10^{12} kw.-hr.)	Approximate [1] coal equivalent (10^6 tons)	Coal equivalent [1] per head (tons)	Potential [1] annual amount coal equivalent per head (tons)
Total sunlight on earth	2.5×10^6	270×10^6	100,000	----------
Hydroelectric power	.3	165	.06	1.4
Wood fuel	[2] 3×10^{10}	200	.08	.25
Wind, etc.	5×10^4	5×10^6	2,000	----------

(*c*) Total controlled power now available:
5×10^{12} kw.-hr. per annum or $2,600 \times 10^6$ tons coal equivalent.[1]
Controlled power now available per head:
2,200 kw.-hr. per annum or 1.1 tons coal equivalent.[1]
Energy value of food now consumed per head:
10^9 calories per annum = 1,100 kw.-hr. per annum or 0.7 tons coal equivalent.[1]

[1] Assuming 20 percent efficiency for coal utilization.
[2] Cubic feet.

TABLE V.—*Distribution of power resources*

[All expressed as percent of world total (coal equivalent)]

	Consumable [1]		Nonconsumable [2]		Total power production (present)	Population percent
	Estimated resources	Estimated production	Potential resources	Production		
United Kingdom	2.8	10	0.07	----------	8.9	2.2
Germany	5.0	18	.2	----------	----------	2.8
U. S. S. R.	19	11	13	----------	----------	8.6
United States of America	44.5	49	15	----------	----------	6.3
India and Pakistan	1.1	1.3	----------	----------	----------	17.5
China	16	1.6	----------	----------	----------	21.0
Japan	.4	2.2	----------	----------	----------	3.3
Europe	29.6	35	14	26	34	22.5
North America	46.5	52	18	37	49.5	8.8
South America	.1	5	16	3	4.6	4.3
Asia	19.8	8	20	32	10.9	57
Africa	3.3	1	30	.3	.9	7.5
Oceania	.7	.5	2	1.2	.5	.5

[1] Coal, oil, natural gas, peat, oil in shale.
[2] Wood and hydroelectric power.

From these we can get the following general view of the present state of affairs. Coal is still the most important single source providing controlled power. It yields an annual amount of energy roughly equal to that from all other sources, both replaceable and irreplaceable, put together. Its consumption has remained fairly stable at about 1,400,000,000 tons per annum for the past few decades, and about nine-tenths of this coal is mined in Europe and North America. These regions possess about three-quarters of the world's known reserves, so that if we were to assume a rate of exploitation of these reserves throughout the world equal to that of the most industrialized communities of the present day, the future world consumption would be around 2,000,000,000 tons per annum. It is possible that large-scale industrialization will spread to areas lacking their own coal resources (Japan is the most significant example of this today) and so lead to a much higher rate of coal consumption, but it is more likely that such increased demands will be met by other, at present underdeveloped, sources of power. In any event, it is difficult to foresee a situation in which a world coal shortage would exist for several centuries.

With respect to the other major expendible source of power, oil, the situation is, however, very different. Its consumption is increasing rapidly; in fact, it has nearly doubled in the past decade. As the basic fuel for transport, it has ousted coal from the role of chief supplier, and for aircraft, road, and agricultural vehicles it is the only fuel of significance; for shipping and railways it is assuming a constantly increasing importance. Extrapolating from the present trends, one might expect that in a decade or so oil will provide as much power as coal, or nearly half the total power. And yet, even at the present rate of consumption, the estimated reserves are sufficient for only some 30 years. No doubt these estimates, as those of the past, will prove conservative, but even with the most optimistic views in this respect it is clear that in the not very distant future a time must come when naturally occurring oil will play a progressively diminishing role in the economcs of world power production.

In contrast with this situation, hydroelectric power is as yet developed only to a very small fraction of its potential and is not subject to the limitation of finite reserves. The full realization of this potential would provide power from this source alone exceeding that available today from all sources. In recent years there has been a marked drive toward fuller exploitation of hydroelectric power, particularly in those countries with or near substantial industrial and highly populated areas but with small fuel resources. Nevertheless, there are today whole continents with enormous resources practically untapped, and hydroelectricity provides less than one-tenth of the world's power.

84. REMARKS PREPARED BY HON. GORDON DEAN, CHAIRMAN, UNITED STATES ATOMIC ENERGY COMMISSION, FOR DELIVERY BEFORE THE CHAMBER OF COMMERCE OF SAN DIEGO, CALIF., MARCH 19, 1952

* * * * * * *

There is one question of interest to the people of southern California that we in the Atomic Energy Commission are frequently asked. It is: "When, if ever, will atomic energy be useful in the conversion of sea water into fresh water for irrigation and municipal use?"

This is a question that we would like to be able to answer with some degree of certainty, but we cannot, for it involves so many factors over which we in the Commission have no control. As I am sure you know, there are today a number of different processes by which sea water can be made fit for human use. This is done every day—on naval ships at sea and on remote island outposts of the armed services. As a matter of fact, when the Commission has a series of weapons tests under way at Eniwetok Atoll in the Pacific, we produce on the order of 200,000 gallons of fresh water daily by conventional means for use by our test-organization personnel.

But these current processes are costly. The processing equipment itself is costly, and the amount of power required to operate it is large in relation to the amount of water produced, which means that it also is costly. I have been told, for example, that to produce 1,000 gallons of water by means of the most efficient process now in use would cost about $1.95, of which about $1.25 would cover maintenance and amortization of the processing equipment, and 70 cents would cover the cost of the power needed to operate it. In contrast to this, the Bureau of Reclamation informs us that charges for irrigation water here in California are in a range of from about one-half to two cents per 1,000 gallons, and for municipal water from 3 to 11 cents. I think it is apparent from this that something must be done about reducing currently high processing costs before large-scale, economical operations will be possible.

Now let's see where atomic energy fits into this picture. In the first place, it has nothing at all to do with that $1.25 figure I gave you. In other words, it does not affect the cost of building and maintaining the processing equipment itself. All that atomic energy can someday be expected to do is to supply the heat or electrical energy needed to operate the equipment. I think it is clear that even if the energy were delivered free it would still not serve to reduce the cost of building and maintaining the equipment.

The time when atomic energy could conceivably become a factor in this equation is when an efficient, inexpensive process for the conversion of sea water into fresh water is developed and is ready to be placed into operation. Presumably it will take energy to make this process work, and it will probably require it in tremendous quantities. It will take energy to make the process work and it will take energy to move the water from the sea to a place where it can be used. This is where atomic energy comes in, for atomic energy is a tremendous potential source of economical power. Today, however, it is not—and it will not be for a good many years.

What this all goes back to, then, is the old story of reducing costs. In this case it means reducing the cost of building and maintaining the water-processing equipment, which is not related in any way to atomic energy development, and it means reducing the cost of the machines that will produce atomic power. The first is somebody else's job; the second is ours. Some day I fully expect that atomic energy devices will be able to produce power that is cheaper than power from other sources, at least in localities where power costs are relatively high. When this day comes, it is conceivable that atomic energy can be used as a power source in the processing and transportation of fresh water derived from sea water, but whether this day will come depends upon a good many factors not related in any way to atomic energy development.

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85. AEC TO CONSIDER ADDITIONAL PROPOSALS FOR INDUSTRIAL PARTICIPATION IN REACTOR PROGRAM

(U. S. Atomic Energy Commission, Washington, D. C., No. 417, April 6, 1952)

The Atomic Energy Commission is ready to consider additional proposals from private industry for preliminary studies of the practicability of privately financed construction and operation of reactors for the production of fissionable materials and power.

In the spring of 1951 the AEC made contracts with four groups of companies for investigations aimed at expanding the participation of private enterprise in the national atomic energy program. At that time only four proposals could be accepted because lack of manpower limited the amount of cooperation available from technical personnel of the AEC and its laboratories and contractors. The four original groups have made interim reports and one has submitted a final report which is now being studied. All of the first series of investigations should be concluded in the near future.

Any agreements with new groups will follow the same lines as the present contracts. The main goals of the studies would include:

(*a*) Determination of the engineering feasibility of design, construction, and operation of a reactor by private enterprise.

(*b*) Examination of the economic and technical aspects of building such a reactor.

(*c*) Measure of the research and development work needed before such a reactor project could be undertaken.

(*d*) Recommendation to the AEC what should be the specific role of industry in carrying out such a reactor project.

As under present agreements, all costs on first phases will be borne by the companies except the time of the AEC and its contractors needed for consultation and information services. The AEC will decide on the distribution of the reports and on the disposition of all inventions and discoveries made in the course of the work.

Security clearances will be granted, after an FBI investigation, to a sufficient number of qualified group representatives to carry out the study. Experience indicates that this would be about 10 persons per company or group.

Any new proposals should be received by the Commission before June 1, 1952.

The proposals to be submitted should contain clearly defined objectives and should be made by financially responsible firms having within their call adequate staffs. Each company or group will work independently of the others.

The eight firms in the four original groups are Monsanto Chemical Co. and its associate, Union Electric Co., both of St. Louis; Detroit Edison Co. of Detroit and Dow Chemical Co. of Midland, Mich.; Commonwealth Edison Co. and Public Service Co. of Northern Illinois, both of Chicago; and Bechtel Corp. and Pacific Gas & Electric Co., both of San Francisco.

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86. UNITED STATES, UNITED KINGDOM, AND CANADA RELEASE ADDITIONAL INFORMATION CONCERNING RESEARCH REACTORS

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 420, April 7, 1952)

The Governments of the United States, the United Kingdom, and Canada have revised the Declassification Guide used by the three nations to determine what atomic energy information held jointly may be published and what information should remain under secrecy.

The revisions are based on the recommendations made by the Fifth International Declassification Conference held September 14–16, 1951, in Washington, D. C., as a continuation of the wartime collaboration of the three nations. The principal revisions to the Declassification Guide will permit the release of additional data on the nuclear properties of uranium, data necessary in the development and understanding of low-power nuclear reactors for atomic research. To speed the development of unclassified reactor technology in the three nations, design and operating data on such reactors was previously declassified in November 1950. The current action will make available to universities and laboratories engaged in unclassified research with nuclear reactors further data that will advance their studies. The three Governments have determined that the release of this technical information will assist the expanding manpower training program involved in the atomic energy efforts of the three nations, and will not aid rival nations in the development of military application of atomic energy. Low-power natural uranium research reactors cannot be used for production of atomic weapons or power.

The revised Declassification Guide permits publication of the thermal neutron cross sections for plutonium 239. Plutonium, basic nuclear reactor fuel, is a fissionable material from which atomic energy can be derived. Its properties with respect to capture and fission by thermal neutrons are similar to the prop-

erties of uranium 235. However, when plutonium 239 fissions from the action of thermal neutrons, it is now revealed that three neutrons are released per fission rather than the 2.5 neutrons released by uranium 235 under similar conditions.

In addition to releasing further information on the low-power research reactors, the revised Declassification Guide permits the publication of the thermal neutron cross section of Xenon 135. This radioactive nucleus, one of the fission products resulting from the fissioning of uranium is a remarkably effective absorber of thermal neutrons. The release of specific technical information on this property of Xenon 135 will be of basic scientific interest in studies of nuclear structure and will aid in fundamental studies of reactor control.

All information declassifiable under the newly revised Declassification Guide must be reviewed prior to publication in accordance with declassification procedures in effect by the three nations. Technical reports will be published in scientific journals concerning the information released.

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87. AEC ACCEPTS DOW-DETROIT EDISON PROPOSAL FOR CONTINUATION OF NUCLEAR POWER PRODUCTION STUDY

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 422, April 22, 1952)

The Atomic Energy Commission has begun negotiations with Dow Chemical Co. and Detroit Edison Co. on their proposal to continue for 1 year, on a jointly financed basis, the Dow-Detroit Edison study of greater industrial participation in the development of nuclear reactors for the production of fissionable materials and power. The work proposed by Dow-Detroit Edison is in line with the AEC reactor development program.

The Dow-Detroit Edison group is one of the four pairs of industrial and power firms participating in preliminary studies as a part of the industrial participation plan first recommended by Dr. Charles A. Thomas of Monsanto Chemical Co. Other groups are Monsanto and Union Electric of St. Louis Commonwealth Edison and Public Service of Northern Illinois, Chicago; and Pacific Gas & Electric and the Bechtel Corp. of San Francisco.

The two companies have estimated their cost of the extended studies at about $250,000. Work to be done by the Commission in this area of research, much of which is already under way or scheduled, may run as high as $750,000. The Commission's action does not constitute a selection among the four. Full consideration will be given to the other proposals as soon as the sponsoring companies submit reports for action by the Commission.

All four teams have submitted interim reports which show a cautious optimism that the difficult technical and cost factors involved will be solved eventually. The Dow-Detroit Edison group is the first to lay before the AEC a specific proposal for going to the next stage—which will include additional research and development work by both the companies and AEC laboratories. The study will involve both reactors and chemical separation processes, but will not provide a final reactor design.

The other teams, as well as Dow-Detroit Edison are studying several general types of reactors, and may submit specific proposals later in the year.

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88. THE PROMISE AND PROBLEMS OF ATOMIC POWER

By Gale Young,[1] Nuclear Development Associates, presented at the Cleveland-Akron section meeting, IAS, Akron, Ohio, April 22, 1952

(From Aeronautical Engineering Review, August 1952. Reprinted by permission of the Aeronautical Engineering Review.)

(1) INTRODUCTION

The past year appears to have been an eventful one for atomic power—probably the most significant period since the early wartime project days. In this paper, I shall consider some of the signs of the times and some of the mani-

[1] Technical Director.

festations that may possibly mark the long shadow of coming events, and include a few remarks about the application of atomic power to aircraft propulsion.

Nuclear fission was discovered only 13 years ago, and the tenth birthday of the atomic project has just been celebrated. Yet the AEC enterprise in its totality has already become so large that I think it must in some manner concern almost everyone, whether he be a personnel manager trying to find scarce technical people, a technical man interested in an expanding new field, a procurement officer pondering where supplies and equipment go when they disappear from the market, a director interested in obtaining supplementary work projects for his company or laboratory, a Government official looking for contractors, or just a humble taxpayer.

(2) MAGNITUDE OF THE AEC OPERATIONS

Just what does this atomic enterprise look like at 10 years of age?

The total expenditure to date has been about $6,000,000,000, of which roughly half has been used while the other half is represented in the existing production plants and laboratories on hand. Thus the AEC is today an interprise with $3,000,000,000 in plant assets. While most of this investment is in outmoded plants and processes inherited from the wartime Manhattan District, it is probably largely this investment that has bought whatever measure of peace and time we have left today. Archaic as these plants and processes may be, they have stood almost alone between us and the aggressor's might.

These $3,000,000,000 in plant and equipment place the AEC near the top of the list—along with A. T. & T. and United States Steel—among the great industrial enterprises. Its installations occupy some 3,000 square miles, an area about equal to the States of Rhode Island and Delaware combined, and its operations extend from the ore fields of the Belgian Congo to the weapon proving grounds of Eniwetok in the Pacific. It employs 120,000 people in its program, although only about 5 percent of these are on direct AEC payroll.

The present rate of expenditure is $1,800,000,000 per year, or about three times the average over the first 10 years. The AEC is in the midst of an expansion that, when completed, will bring the total plant investment to $4,500,000,000. The two big current installations are the isotope separation plant at Paducah, Ky., and the plant at Savannah River, S. C., for making atomic-bomb and hydrogen-bomb materials. The investment in the Paducah and Savannah River plants combined will about equal the plant holdings ($1,800,000,000) of the General Motors Corp.; the Savannah River plant alone ($1,300,000,000) will somewhat exceed the total plant investment of the du Pont Co. that is building the Savannah River installation for the Commission.

It would clearly be impossible, in a paper of this kind, to do justice to the myriad engineering problems and details in an operation of this magnitude. Therefore, let me conclude this barest sketch of the AEC enterprise with a few bits of comparative data about its use of scarce commodities, as shown in table 1.

TABLE I

Commodity	Total United States supply	Amount used by AEC	Percent of total used by AEC
Nickel			7
Sulfur			5
Stainless-steel tubing			50
Electric power			2
Engineers	400,000	[1] 8,000	2
Physicists	12,000	1,200	10
Total scientific and engineering population			5
Construction workers	3,000,000	60,000	2
Mathematical physicists and nuclear physicists	350		

[1] One-quarter mechanical, one-quarter electrical and radio, and smaller numbers in other engineering categories.

These numbers are current values, and all are rising and will rise further even without any AEC expansion over and beyond what was already under way at the end of 1951. Thus, the more recent proposals for a severalfold new expansion of the AEC program would presumably call for something like a severalfold multiplication of percentages in table 1.

A singularly unhappy note is that struck by the item concerning electric power. In spite of the 100 kilowatts of electrical energy recently produced from a reactor at Arco, it appears that the books and face of the atomic business are much in the red on the subject of power. To quote Commission Chairman Dean: "The atomic energy program is consuming power at a rate which by next June will be comparable to that of New York City, or roughly 2 percent of the total national supply, and this demand will increase enormously as additional new plants now under construction come in. For example, our new uranium separation plant now being built at Paducah, Ky., will have a power demand of about 1,000,000 kilowatts. * * * The fact remains that while the world ultimately looks to the atom to produce power, the atomic energy program is today the largest single consumer of power. * * *"

(3) RECENT EVENTS OF SIGNIFICANCE FOR ATOMIC POWER

(3.1) *Projected expansion of AEC*

There have been recent proposals for vast further expansion of the atomic program. Senator McMahon, chairman of the Joint Congressional Committee on Atomic Energy, last year introduced a resolution into Congress urging that the program be raised to a $6,000,000,000 annual rate. His committee requested the AEC and the Department of Defense to prepare a detailed program for maximum expansion of the program. Subsequently President Truman indicated that a new $5,000,000,000 or $6,000,000,000 expansion in AEC facilities is contemplated during the next several years;[2] added to the $4,500,000,000 in plants which will exist at the completion of the present phase of expansion, this gives the AEC a $10,000,000,000 total plant investment in the future.

Thus, the atomic program is apparently going to be expanded as fast as it can absorb funds poured into it. While this expansion is motivated by weapon needs, it must surely be of significance for atomic power as well. Even if this money were to be spent entirely in duplicating the venerable outmoded plants that the AEC operates today (the isotope separate plants that sop up huge quantities of power instead of producing it, and the Hanford reactors that throw their heat away uselessly down the Columbia River—both of them merely skimming a little of the top cream off the costly uranium ore before discarding it to waste)[3] it would surely benefit atomic power. You cannot spend that much money on anything atomic, and bring into the program that many bright engineers, physicists, etc., without getting additional ideas and know-how. There must be at least some minimum measure of atomic power significance attached to the coming AEC expansion.

Actually, the Commission has lately indicated that it is on the trail of much more advanced processes (breeder reactors), and, if some substantial fraction of the coming expansion can go into this new kind of plant, the significance will be greatly increased.

(3.2) *Mobile reactor progress*

The most positive and definite assurance of atomic power, at least in some limited form, comes from the mobile reactor program being undertaken for military vehicles. It has been known for some time that work was under way on reactors for the propulsion of submarines and aircraft. This past year saw unmistakable signs of progress and decision in both endeavors.

In the submarine department (where Capt. H. G. Rickover has had a strong guiding hand throughout), there are two major branches. One involves the Argonne National Laboratory and the Westinghouse Electric Corp., and the other is at the General Electric Co. The Argonne-Westinghouse reactor appears to be far along, indeed. Construction of the first land-based prototype at the Arco test station has been under way for some time, and the Navy has contracted with the Electric Boat Co. to construct the hull for the first submarine proper (which the Navy has already named the U. S. S. *Nautilus*, and expects to have ready in 1954). The General Electric reactor is also to be first operated as a land-base prototype.

In the aircraft department, there were several important developments during 1951. It was announced that the NEPA (Nuclear Energy for the Propulsion of Aircraft) preliminary study project had finished its work. Contracts were

[2] Marking the beginning of this expansion is a current announcement by the AEC that it is looking for a site for another isotope separation plant to cost $1,000,000,000 and to consume 1,800,000 kilowatts of electrical power.

[3] The Savannah River plant is similar in nature to the Hanford facility.

given by the AEC and the Air Force to the General Electric aircraft gas turbine department to construct the reactor and power plant for an airplane, while the Air Force contract for construction of the corresponding airframe went to the Consolidated Vultee Aircraft Corp. This was big news in the aircraft atomic propulsion business; these were major companies, and they were being given major contracts actually to build a flying machine. Clearly, there was something in the wind. Then came the news at the end of the year that Pratt & Whitney had been given an Air Force contract to develop another and different aircraft reactor and power plant.[4] Let us again quote Chairman Dean, who says:

"We are much farther along on the submarine reactor than we are on the aircraft one, but I am sure in my own mind that eventually we are going to have both; and as a special bonus we are going to pick up a lot of technical know-how that will help us immeasurably in cutting the costs of atomic power for commercial use. What we are doing, essentially, is charging a good share of the high development costs of power reactors to national security, and, in the process, getting at the earliest date possible a kind of propulsion unit that will reduce almost to the vanishing point the dependence of naval vessels and military aircraft upon bases of fuel supply."

(3.3) Entry of industrial companies into the atomic-power field

The mobile reactor developments assure us, as much as anything can be assured in a new field, that there is going to be some use of atomic energy for power purposes—namely, to drive military vehicles. But this is not what the man in the street means by atomic power. He means something that will bring electricity into his home economically or be of service in his peacetime industries. As the above quotation from Chairman Dean indicates, this latter is a less immediate prospect.

However, even here there are important developments. This past year has seen four teams of industrial companies, under arrangement with the AEC, start spending their own money—at least $1,000,000—in atomic power studies. There is a Michigan team (Dow Chemical and Detroit Edison), a St. Louis team (Monsanto Chemical and Union Electric), a California team (Brechtel and Pacific Gas & Electric), and a Chicago team (Commonwealth Edison and Public Service). The agreements provide for surveys and studies by the companies (*a*) to determine the engineering feasibility of their designing, constructing, and operating dual-purpose reactors to produce fissionable materials and power; (*b*) to examine the economic and technical aspects of building such reactors in the next few years; (*c*) to determine the possible research and development needed; and (*d*) to recommend industry's role in designing, building, and operating such reactors.

Commissioner Glennan comments: "What will they come up with? I don't know but I am satisfied that much of value will appear in their reports. You just can't let intelligent, aggressive engineers and management people loose in this business and draw a blank as a result of their efforts. No one of these companies will willingly throw away the money they are spending on these surveys. As a minimum, then, let's say that I am more than mildly enthusiastic on this deal."

(3.4) Breeder reactor announcement

The past year saw several news items about peacetime applications of atomic energy. The British project revealed that it is using reactor output for the space heating of buildings. The AEC announced that the Argonne National Laboratory had produced the first known electrical power (100 kilowatts) from a reactor; the Commission's report shows photographs (reproduced herein) taken by the light of this electricity. Subsequently, Oak Ridge National Laboratory disclosed that it, too, has a reactor under construction which will generate some electrical energy. These developments are encouraging, but I doubt if they carry much significance in themselves. To the public, which has been awaiting such news for a long time, the principal connotation is merely a feeling of relief that these announcements have come at last. But, while somewhat playing down the significance of the power announcement as such, I would emphasize strongly another aspect of the same story, namely, it was an experimental breeder reactor from which this power was produced. Herein lies the real significance of the announcement, and here lies the real road to the future.

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[4] It has been further announced that Boeing is to work on an airframe in connection with the Pratt & Whitney engine project.

You will recall that the fission chain reactor is possible only because a fission, which uses up one neutron, in turn produces more than one neutron. Thus, the neutron output from one fission suffices to set off the next fission, etc. Thus, if one has a supply of fissionable material, one can proceed to burn it via the neutron chain and so obtain energy. This is what the project has been doing thus far. Some fissionable material—namely, the rare isotope 235 of uranium—is found in nature in tiny amounts, and the project consumes this to produce energy in atomic bombs, mobile reactors, etc., by the now familiar processes developed in the Manhattan District under General Groves.

The new breeding process being developed by the AEC goes much further and makes each fission replace not only the consumed neutron but also the consumed atom of fissionable material as well. This is possible because, first, each fission produces 2½ neutrons[5] so that, even after you subtract the one neutron needed for the next fission, there are 1½ neutrons left; second, if you have a neutron, you can make an atom of fissionable material by absorbing the neutron in a so-called fertile material. Thus, if you are careful not to waste any neutrons in the process (which is one of the big development problems, since neutrons tend to be absorbed by anything and everything you put in the reactor for structure, cooling, etc.), you can make 1½ atoms of fissionable material for each one you destroy. Hence, your breeder reactor not only sustains itself on fissionable material, but continuously exports an excess of one fuel atom for each two it consumes.

Here, then, is the coming facility that makes obsolete the plants that the AEC is today operating—a power-producing breeder reactor (either stationary for industrial use or mobile for military or transportation purposes) which steadily exports fissionable material for weapons or other use. The required fertile materials (uranium 238 and thorium 232) exist in nature in much (several hundred times) greater abundance than the natural fissionable material (uranium 235) now being exploited. Thus, the breeder reactor enables us to expand the atomic program a hundredfold, if desired, and, at the same time, be freed from depending upon foreign ore supplies in remote and vulnerable corners of the world.

This is a key development that warrants the greatest all-out effort. Senator McMahon, who sounded the first note in the vast new expansion of the atomic-energy program, says in the 1951 report of his Joint Congressional Atomic Energy Committee: "The committee also renews its 1949 recommendation, particularly as regards thorium breeders and plutonium production reactors of the future, that 'reactor development * * * proceed with all possible speed' * * * there are opportunities for faster advancement which need to be vigorously exploited. If the committee has a single general comment to offer, it is this: Greater boldness and more scientific and technical daring should be brought to bear upon the program."

Thus, the first power came from an experimental breeder reactor and in this is a manifestation of the boldness and daring Senator McMahon urged. As people interested in the development of atomic power, as citizens who want our atomic program to be of the best and our country to be in the strongest position possible, and as taxpayers who do not want to see the Nation saddled with any more billions of dollars worth of antiquated atomic plants than necessary, let us hope for the continued fast advancement and vigorous exploitation that will see breeder reactors playing a major role in the coming new expansion.

(4) MAJOR PROBLEMS

Having reported to you on some of the more significant atomic power news of the last year, next, I should like to distinguish some of the larger problem areas and make a few comments on some of the more specific topics involved. Various of the frequently encountered technical items have often been described in the literature. For example, Dr. Hafstad notes the inability of materials to stand high temperatures, show minimum radiation damage (under the intense bombardment of neutrons, gamma rays, etc., in the interior of a reactor), and not

[5] The AEC has just revealed that under some conditions the number of neutrons per fission is as large as 3, which improves the breeding picture given here.

absorb and waste an excessive proportion of the available neutrons. He also notes the problems of shielding personnel and instruments against the adverse effects of radiation, obtaining control gear with response times adequate for safety, effecting heat-transfer rates higher by an order of magnitude than those conventionally used, dealing with fission products that jeopardize neutron economy, and handling and ultimately disposing of radioactive waste in a manner that will constitute the minimum health hazard.

(4.1) Raw materials

The starting point of atomic energy work lies, of course, with the raw materials (uranium and thorium) employed. The emphasis to date has been primarily on uranium, which already contains a small fraction of fissionable material (1 part in 140) which can be exploited, rather than on thorium, which can be utilized only in a breeding process. These raw materials are radioactive and are slowly decaying and will eventually turn into lead. There need be no concern that atomic power may not be developed before the raw materials are lost. This worry is completely unjustified, since these materials take a few billion years to decay, and we are assuredly making progress much more rapidly than that.

Estimates of uranium in the earth's crust run from 3 to 8 parts per million by weight and for thorium from 10 to 30 parts per million. Using nominal values of 5 for uranium and 15 for thorium gives a total of 20 parts per million. Since the energy output per unit weight is about 2,500,000 times as great for fissionable material as for coal, we see that a ton of average earth crust is potentially equivalent (assuming breeding to utilize fully the raw material) to 50 tons of coal. (See similar remarks by Akers.)

Granting that the earth we walk on is energywise 50 times as rich as a solid bed of coal, what about the costs of extracting materials? On this, only the roughest of estimates are available. Menke, from a survey of costs in a number of other cases, has estimated the price of extracted materials to be about $10 per ton of ore handled. Using this as a guess sounds encouraging, since it would say that the energy equivalent of 50 tons of coal can be obtained for $10, even if we ignore the value of any byproducts obtained in processing the earth's crust. Similar suggestions have been made for "mining" sea water. Here, the uranium and thorium concentrations are much lower.

The above values of $10 per ton at 20 parts-per-million concentration would give a cost of $250 per pound for uranium and thorium recovered from average earth-crust ore. From richer-than-average ore the cost should, of course, be correspondingly lower. While I do not believe full data on AEC uranium costs have been published, price schedules paid to miners for ore have been published, and these go up [6] to several dollars per pound of contained uranium. A Canadian article discusses the process used in extracting the uranium from the ore and implies costs of a few dollars per pound of uranium for this separation step. Adding "several" to "a few" gives approximately $10 per pound as an estimate for the current price of uranium.

A cost of $10 per pound marks a fairly expensive material, and, needless to say, the procurement of raw materials for the project is a big business dollarwise. Since the prospecting, as well as the mining and concentrating, of the basic raw materials is one of the major areas for the application of engineering effort and ingenuity, I should like to call it to your attention.

Extensive exploration work is under way to locate further deposits, and recovery of uranium from gold-ore residues in South Africa and from fertilizer phosphate rock in the United States has been announced.

Some of the darker parts of the picture are: (1) The breeding process is not yet in hand, and, without it, the raw material situation is immediately some 500 times worse; (2) atomic power is at peculiar disadvantage with respect to the inventory of material which has to be on hand. You are doubtless familiar with the phenomenon of "critical mass" which has been frequently discussed—namely, that a small amount of fissionable material will not operate by itself and that a large amount of fuel must be assembled in order to get a chain reaction at all. Much the same sort of thing applies also in breeding and for much the same reasons. It is easy enough to say that we shall capture the excess neutrons in fertile material and thus make fissionable fuel; however, the neutrons tend to diffuse for considerable distances and thus escape from the system, and they also tend to get uselessly absorbed in other material in the system. Thus, to

[6] Including bonuses, development allowances, transportation allowances, etc.

capture the neutrons effectively in practice requires the use of a large amount of the desired capturing (i. e., the fertile) material.

I do not have an especially good example to illustrate this point, but we can get a quantitative impression by looking at the famous Canadian reactor that was announced as having the highest neutron flux in the world. I always thought it was the atomic news story of the year when Dr. Hafstad revealed 3 years ago, that the Canadians had a higher intensity reactor than we possessed, but it did not seem to bring forth much comment in the press. Perhaps Dr. Hafstad dropped his bombshell too quietly, or perhaps there was at the time too much heated discussion about whether we were properly keeping our atomic secrets. However, the news that we had slipped to second place in an important respect went apparently almost unnoticed. So far as I know we still do not have a reactor to match the Canadian machine. This Canadian reactor has a flux of 6×10^{13} neutrons per square centimeter per second, and an atom of fissionable material has a cross section or target area for neutrons of about 500×10^{-24} cm.^{2}. Upon multiplying these numbers together, it is seen that 3×10^{-8} of the fissionable atoms are hit by a neutron in 1 second. It follows that the reactor contains $\frac{1}{3}\times10^{8}$ seconds or about 1 year's supply of fissionable material. Since this is a natural uranium reactor, the amount of fertile material is 140 times greater, or a 140 years' supply for a breeding process.

With such huge inventories, even a low-price fuel can become a major investment item. If the hold-up time is 140 years and the fixed charges (interest, insurance, taxes, etc.) are 7 percent annually, then the inventory cost is 10 times the destruction cost. Such numbers indicate that the search for richer ore deposits or cheaper mining methods may be spurred more by inventory requirements than by the cost of fuel destroyed. This factor of 10 suggests[7] that breeding is 50 (rather than 500) times better on raw material charges than simple exploitation of the natural fissionable material; the "hold-up" factor of 10 obtained here is only a rough impression and is, of course, subject to improvement through design effort—e. g., raising the neutron flux would decrease the hold-up time.

In any case, I would like to leave with you as a first major engineering problem and challenge the mining of increased quantities of raw materials at lower prices. It is a most important area and can be a highly rewarding one. Dr. C. E. Larson, Director of Oak Ridge National Laboratory, was recently quoted as saying that the future of atomic development in the United States depends on recovery of uranium from low-grade ores.

(4.2) *Aircraft reactors*

As was mentioned earlier, the mobile reactor program has at present two substantial branches concerned, respectively, with submarines and with airplanes. Of these two, I shall deal primarily with the airplane program.

These two reactor programs have been under way for about the same length of time, and the submarine development is farther along primarily because it is the less difficult of the two. The atomic-powered airplane is an extremely difficult development. Indeed, it seems fair to say that, with the possible exception of economical commercial atomic power itself, the airplane problem is the most difficult one the project has. The difficulties encountered in the aircraft program have been described by Dr. M. C. Leverett, of the General Electric aircraft nuclear propulsion project, in a talk before the IAS Chicago section about 6 months ago. They stem largely from the large shield weights required by reactors and the high temperatures required by airplane power plants. Dr. Leverett indicates that the necessary shield weight is some 50 to 100 tons, which is just about what can be carried by the largest airplanes in existence. Such large planes require large power outputs to propel them, and, thus, the reactor, which has meantime been made small in order to keep down the weight of the shield surrounding it, winds up in the unhappy position of having to generate and remove large amounts of heat from a small volume. This particular difficulty is known as high specific power (i. e., high power output required per unit reactor volume) and is possessed by the aircraft reactor to an uncommon degree. You can readily picture the horde of troubles that this engenders—fine scale structure, high coolant velocities, large pressure drops, high heat fluxes, and large temperature differences, thermal stresses, etc.

A reactor for aircraft service is also caught in the cross-fire of a second major difficulty; namely, the uncommonly high temperature called for in this application.

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[7] This hold-up cost factor of 10 does not apply at present when we have a large stockpile of fertile material (depleted uranium from the project) which is idle.

The problems encountered in pushing materials up to the temperatures reached in modern military aircraft power plants are familiar. The same problem is encountered in the reactor, except that (*a*) every time you propose a material to put into the reactor there will be somebody who wants to take it out because it absorbs too many neutrons, and (*b*) people will insist on putting into the reactor materials of which you have never heard.

Dr. Leverett remarks that just about every type of aircraft propulsion machinery has been proposed for use with a reactor but does not indicate what the actual choice will be. On this point, I recall only two authoritative statements. About 2 years ago, Dr. Andrew Kalitinsky, who was at the time chief engineer of the NEPA project, told a meeting of the IAS that a turbojet system might be the easiest way of applying atomic power to aircraft. When it was announced last year that the first design contact in this field had been given to the GE aircraft gas turbine department—a division that specializes in turbojet engines—it seemed for a while that this supported Kalitinsky's opinion. However, just 2 months ago this year, Dr. Alvin Weinberg, Research Director of Oak Ridge National Laboratory, was quoted as indicating that, as far as present thinking went, an atomic aircraft engine would probably deliver power through a steam turbine.

(*4.3*) *Breeder reactors*

The main theme of what remains to be discussed concerns the problem of economy, and this will serve also to point out the close tie-in of the subject of breeding with my next topic of industrial power.

In a breeder reactor, the neutrons released by a fission go (*a*) to replace the neutron consumed in the fission and (*b*) to replace (or more than replace) the fuel atom consumed in the fission via neutron capture in fertile material to produce fissionable material. It is thus clear that neutron economy will be of much concern and that no large loss of neutrons by useless parasitic capture in reactor materials can be tolerated.

Another point to be noted is that things have to be done to the fertile material and operations carried out on it before it becomes fissionable material. Thus, if the raw material could be mined directly in fissionable form instead of in fertile form that has to be processed further, it would certainly be cheaper than breeding. Unfortunately this is not the case, and only a small fraction (1 part in 500) of the raw material is naturally fissionable. The present project operations amount to seizing upon and exploiting this small fraction of the raw material, the remaining large fraction being essentially discarded. Even this small fraction is not available free after the ore has been obtained, and further processing, such as in the expensive power-consuming isotope separation plants, is needed before pure fissionable material is obtained.

Thus we see that breeding gets unavoidably into the large question of dollar economy. The processes it involves must not only be developed but they must be developed so that they can be carried out economically. In situations of this sort, the primitive operation (in the present case, our exploitation of U–235 by the methods of the Manhattan District) can get so entrenched behind big plant investments, etc., that the desirable ultimate operation can even be inhibited or discouraged, with the money continuing to go into what was done yesterday instead of into what should be done tomorrow.

While the Commission's announcement of the Argonne breeder reactor is careful to say that it is only an experimental machine and that much further development is needed, let us continue to hope that this is nonetheless a sign that we are breaking out of the Manhattan District's primitive U–235 trap and that the road to tomorrow is being blazed with all possible vigor and determination.

Nothing short of true breeding can achieve the goal of multiplying our raw material stockpile by factors like 100 and assure us of a sufficient supply for all conceivable military developments and industrial power advances. It is, in passing, a little ironical to note that the bred fuels (U–233 and Pu–239) are the one that are potentially available in large amounts and that the one (U–235) whose tiny amount we are so busy using up is the one that will be most difficult to replace.

(*4.4*) *Industrial power*

What now, finally, of the big question that the man in the street has been asking for so long—Is there going to be commercial atomic power? This question has been debated at such length and with such vigor that it would be difficult to have any new opinions about it. The real inside information on this is fortunately

not secret and can be conveniently assembled in the following statement. "Atomic power will be economical if you can make it cheap enough."

This remark serves to set the stage for the coming development battle for atomic power—a battle that is just now being joined and which will be won or lost largely in terms of success in cutting costs and finding more economical processes.

I have mentioned the many diverse opinions that have been expressed about the outcome of this struggle and about the prospects for atomic power. Let me give you two contrasts and a few singletons from among these.

Last September at the Chemical Society meetings in New York, two eminent gentlemen spoke on this subject. Dr. Conant, of Harvard, upheld the negative and pictured the atomic-power game as turning out about a decade from now to be not worth the candle, with worried mankind eventually finding a way out of the atomic age and into an age of plenty based on solar energy. He spoke of the worry about coal supplies as increasing by the end of this century. On the other hand, Dr. Grebe, of Dow Chemical Co. (who is one of the men participating in the current atomic power studies by industrial companies mentioned earlier), sees a serious situation looming now in the electrical power field where mounting costs have finally overtaken engineering ingenuity, with the result that power prices, which have been continually going down for years, have at last started back upward. He fears that this reversal in trend of such a basic commodity as power will have an adverse effect on our national productivity and looks to atomic power to tip the scales the other way and help make possible the continuation of the remarkable growth curve of the United States. He remarks that "the rapid increase in total heat energy consumption, particularly the electrical power production, now doubling every 9 years, can no longer be supplied from the current rate of production of coal," and, thus, further increases in the already high prices of coal are to be expected.

For a second, and much milder, contrast let me go back to 1948 when two other eminent gentlemen (physicists, this time) spoke on these same subjects. Professor Wigner, of Princeton, did not expect atomic power to assume any decisive economic importance so long as the present period of abundance of fossil fuels continues, and, even when these near exhaustion, it will have to compete with other sources such as solar energy. Professor Pryce, of Oxford, on the other hand, expresses hope that atomic power may come along quickly enough to provide some relief of the present fossil fuel shortage and that the atomic raw materials may "last sufficiently long to allow human ingenuity to find new sources of power before they run out."

Many of the differences in these several points of view appear to arise from different opinions as to the fossil fuel resources, with the British and the engineers being more pessimistic on this score and American scientists more optimistic. Dr. Grebe in fact remarks that the British should lead in the early production of atomic power because they need it more.

Let us note now an opinion from Canada (where, as I mentioned earlier, the world's most advanced reactor has been in operation for some time). Two years ago Canadian scientists believed significant civilian use of atomic energy was from 20 to 30 years away. By 2 months ago, they had changed their minds. The Government formed a Crown Company, Atomic Energy of Canada, Ltd., to take over the Chalk River project in Ontario, the main center of atomic research. Prime Minister Louis St. Laurent announced: "The prospects for early and useful application of atomic energy have become more promising."

Finally, about 1 month ago, Chairman Dean of the USAEC offered a guess that atomic energy might be used for limited commercial electric power production within 5 to 10 years.

All this appears to be showing signs of adding up to something. In atomic circles, there is a quickening of interest all along the line and a heightened feeling of vigor and boldness and of things impending. I am not sure just what has brought this about. Perhaps it was triggered, as much as by anything, by a proposal of Dr. Charles Thomas, president of Monsanto Chemical Co. Dr. Thomas suggested that, since industry wants power and the AEC wants fissionable material and since reactors can produce both, the two might get together in some way, with industry building and operating reactors for power and the AEC purchasing the resulting fissionable material at a price that would make the operation feasible. This idea seemed to have appeal all around, and it was not long before the AEC had completed arrangements with a number of companies (including that of Dr. Thomas) to look into the possibility. Thus, the atomic-power studies by the four industrial teams mentioned previously were begun.

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Dr. Grebe's paper represents the only report we have had from the industrial studies. After expressing his concern about the deteriorating fossil fuel and power situation, as I mentioned earlier, Dr. Grebe goes on to discuss the prospects for atomic power development.

The main theme of Dr. Grebe's paper is "invent cheaper processes—drive costs down," and this same theme runs through many other discussions of the subject.

Why, then, are the atomic power costs so high? Perhaps in closing I can attempt to give you some idea of the high costs about which everyone is so concerned. Undoubtedly, a large share of these costs stems from a single word, "radiation." If it were not for the dangerous radiations involved or if we were somehow immune to these radiations, we might have atomic power now. Imagine, if you will, that the aircraft engines with which you are familiar could only be operated within thick vaults and that everything in them became intensely radioactive, and I think you will get some idea of what the reactor engineer is up against. The difficulties of remote-control engineering have been well stressed by Dr. Simpson; you have merely to translate these into costs in dollars and time to see why the project is both slow and expensive. Even the simplest of operations—e. g., tightening a bolt—can become inordinately expensive and time-consuming if it has to be done by remote control through a thick wall of a building or by a man working from within a heavy crane cab.

Reactors will not let you go away and ignore their unpleasant contents. To quote from former Chairman Lilienthal: "When fission takes place energy is released. * * * But something is left behind, the result of splitting the nucleus. This mixture of the isotopes of many elements is very radioactive. Inside the reactor, where all this takes place, the effect of these 'hot' elements on the operation of the reactor is bad. Some of the new elements absorb neutrons readily, so that their effect is to quench the nuclear reaction. The fission products—the neuclear ashes—must be removed and the remaining nuclear fuel recovered to be used again. This is a chemical separation job that presents some highly complex and difficult problems of chemistry, chemical engineering, and metallurgy—and it must be carried out by remote control to protect the workers from lethal radiations. I need not stress the troubles of this kind of operation by mechanical proxy, nor need I stress the economic importance of efficient recovery of the unspent nuclear fuel, for this is material that may not under any circumstances be wasted."

In briefest sketch, then, we can outline the operations and problems of an atomic power plant as follows. First, one obtains the raw material—the fertile material that turns into fissionable material when it captures neutrons. Evidently, this material has to be arranged so as to surround completely the part of the reactor where the fissions occur, or else neutrons would escape and be lost. This surrounding outer layer of fertile material is commonly called the breeding blanket, and the central region where the fissions occur is termed the "core" of the reactor. The blanket has to be thick enough to catch all the excess neutrons leaving the core, and it has to be cooled without introducing neutron absorbers to any significant extent; there is a high premium on neutron economy in a breeder reactor. Now we come to the "processing" headache so vividly described by Mr. Lilienthal. The fuel is created in the blanket, and we want to remove it for export or to transfer it to the core where it is burned. This must be done in spite of the intense radioactivity; it must be done without losing precious fuel or fertile material, and it must be done economically. How it is, in fact, going to be done, I have no idea, but some day engineers will figure it out and then we will have atomic power.

After the fuel has entered the core, much the same applies. It must be cooled (more strongly now, because here is where most of the heat is produced) without wasting neutrons; it has to be processed over and over again to remove fission products, again economically in spite of the intense radioactivity and without wasting fuel.

Because a breeder with its associated fertile and fissionable material is an expensive machine, as much power as possible must be extracted from it. Thus you will again be led into the high specific power difficulties I mentioned in connection with aircraft reactors. Also, since you will want good efficiency in your power plants, you will be led into the problems associated with high reactor temperatures. Thus, in these respects, more or less, what must be done in getting an aircraft reactor must be done again, except that this time it must be done economically. Then we will have atomic power.

89. AEC ESTABLISHES OFFICE OF INDUSTRIAL DEVELOPMENT HEADED BY DR. WILLIAM LEE DAVIDSON

(U. S. Atomic Energy Commission, Washington, D. C., No. 423, May 1, 1952)

Effective today, the Atomic Energy Commission is establishing at Washington headquarters a new Office of Industrial Development headed by Dr. William Lee Davidson, formerly director of physical research for the B. F. Goodrich Co., Akron, Ohio.

M. W. Boyer, AEC general manager, said the purpose of the new office would be to aid in the administration of the industrial-participation program, involving studies of power generation, and to expand the areas in which all types of industry may find an interest in the national atomic-energy program.

"The Commission's program of industrial development," said Mr. Boyer, "will be a two-way exchange. We want to make sure that the developments in the national atomic-energy program which may have application in industry are promptly made available to the people interested.

"Dr. Davidson's office will provide a point of contact with positive responsibility to foster wider industrial participation in the Commission's program and the development, as may be possible, of a more normal competitive approach to the problems and potentials of the atomic-energy business.

"The Commission's establishment of an industrial-development office has important long-range implications, looking to the day when industry will carry on its own a substantial part of the national atomic-energy program. Of immediate importance, however, is the support of the present defense effort which we expect to result from an intensive effort to bring about a fuller utilization of both Government and industrial technological resources. This will require, among other actions, an expansion of the Commission's technical-information services, which have emphasized aids to scientific research for the acquisition of new knowledge rather than for its application in industry."

Dr. Davidson was director of physical research for the B. F. Goodrich Co. from 1947 until taking the AEC assignment. Before joining Goodrich he was with Monsanto Chemical Co. for a year, during which period he attended the first class in reactor technology at Oak Ridge National Laboratory and worked in the field of neutron-diffraction theory.

Obtaining his doctor's degree in physics at Yale in 1940, Dr. Davidson spent 6 years with Goodrich as a research physicist, working on bullet-sealing fuel cells for aircraft and other products allied to rubber. He also carried out studies in the fields of X-ray and electron diffraction and worked on the development of radioactive tracer techniques. Dr. Davidson is coauthor of Applied Nuclear Physics.

A native of Jonesville, Va., Dr. Davidson was graduated from the College of William and Mary in 1936. In 1950 he was given the distinguished-service award of both the Akron and the Ohio State Junior Chamber of Commerce. He is a member of the American Physical Society and the American Chemical Society.

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90. HOUSE OF LORDS DEBATE ON SCIENCE AND INDUSTRY ON JUNE 12, 1952

(Quoted from Atomic Scientists' News, London, September 1952)

Lord CHERWELL. The next matter that comes to my mind is the question about nuclear energy. I must congratulate the noble viscount, Lord Samuel, on using the word "nuclear." I have pleaded for its use from the beginning. I dislike that dreadful phrase "atomic energy," which means nothing, because every time you digest a bit of bread you are using atomic energy. I am very glad to see that that term is being superseded, at any rate in this House. But really the question of using atomic energy——

Lord STRABOLGI. Nuclear energy.

Lord CHERWELL. It is very easy to fall into bad habits in bad company. I was going to say that the question of using nuclear energy has been before us for 6 or 7 years, and it has always been considered from the point of using it for peaceful purposes. In the earliest days, wild prospects were held out and it was claimed that soon everyone would have energy to spare. But, of course, that has not come to pass. I think the noble lord will be pleased to learn that prospects really are improving. Nobody claims that nuclear energy will be cheaper than

energy from coal. All it will be able to do, at any rate in the immediate foreseeable future, will be to replace some of the ordinary fuel we use today. Of course the more expensive coal gets, the more attractive will nuclear energy become. In 1951, we used 35,000,000 tons of coal for making electricity, and in 1960 we reckon that we shall require 13,000,000 tons more. I do not say definitely that it will be so, but it may be that in about that period of time people will seriously consider installing nuclear reactors when they are debating how to make their new power stations. It must be remembered, however, that nuclear reactors replace merely the boilers. You must have all the rest of your system, your steam engine, or whatever it may be, your dynamo and distribution network. The trouble about nuclear reactors is that their capital cost is high. In the ordinary pile such as we have already working, we can use less than 1 percent of the charge of uranium. One ton of uranium, if we could use the whole of it, would be equivalent to 2,000,000 or 3,000,000 tons of coal. If we use only 1 percent, it would take 100 tons of uranium to give us even a fraction of our coal consumption for electrical power—something like 5 percent—and uranium is by no means easy to come by. The whole world is being searched for uranium, and 100 tons is quite a notable amount.

When nuclear energy is used for producing bombs and for explosive purposes, you get heat as a byproduct. Noble lords no doubt have seen that some of the houses at Harwell are being warmed by heat generated in one of the piles there. It may be used for something else, like heating a market garden; but the immediate use is circumscribed. In a few years we hope to test one of these piles made deliberately in order to produce energy, combined with a steam engine or something like that. It will not be very economical, but it will work. It will be interesting and we shall learn many lessons from it. But if we were condemned to use only 1 part in 137 of the uranium, then it would not be interesting from an economic viewpoint. But there is a hope of making what is called a breeder reactor. There you have fast neutrons; you do not slow them down by using graphite or heavy water, and let them react with enriched uranium or plutonium. The reactor uses the same principle as the bomb; it is in fact a controlled bomb. Many neutrons, of course, escape; if you surround the breeder with either thorium, which is fairly common, or uranium 238, the heavy isotope, which cannot normally be used, then the escaping neutrons produce in it either an isotope of uranium of atomic weight 233 or plutonium. If you start with uranium 238, the escaping neutrons breed plutonium and this can be extracted and put into the middle to breed fresh material. And in this way you can go on getting power and breeding fresh fissile material as long as you have thorium or uranium 238 with which to surround the reactor proper. It may be that by this method we shall be able to use the whole of the uranium, or at any rate a very large proportion—60 percent, or something like that.

That sort of project, of course, presents the most extraordinary novel technical difficulties. We are fortunate in having Sir Christopher Hinton, one of the best engineers in this country, and Sir John Cockcroft, one of our outstanding physicists, cooperating in trying to design such fast reactors, but it involves an enormous number of new problems, just the sort of problems which the professors in a technological university should be studying in the course of their work. There are a lot of metallurgical problems; many odd metals like beryllium or zirconium have to be produced and examined to see if they have suitable properties. We have to find methods of extracting light uranium and plutonium, which we have more or less mastered. And we have to get the heat away. If you have a collection of uranium rods producing all this heat, thousands of kilowatts of energy, it is none to easy to get the heat away from the surface. Probably some method of liquid-metal coolant will have to be used for that. Heat transfer is just the sort of thing that would be studied in the technological university in its own right.

Then, of course, there is the operating technique to control such a system. As I have said, it would be a sort of controlled bomb, so the technique must be foolproof. We have to find ways of extracting from the blanket fissile material which has been bred in it. We have to find out the effect of this intense neutron bombardment on the vessels used. It is certainly a long-time investigation, and it will require in the end considerable capital investment. But I am sure that it is well worth doing, and I think the prospects of success are considerable, perhaps within a reasonable number of years. There is also this to be said. There is a great advantage in making these nuclear bombs in place of ordinary explosives in that, if you do not use them as bombs, you can use the materials for

these reactors. However much TNT you may have, it cannot be used to drive an engine, and at the end of a war it usually has to be thrown into the sea.

Lord STRABOLGI. My lords, I hesitate to interrupt the noble lord's interesting discourse. Once you have made the bombs, you cannot then use that material in them? You cannot scrap them again and reuse the material?

Lord CHERWELL. Oh, yes; you can, perfectly easily. There would be no difficulty in beating our plutonium into power plants. But there are limits to the availability of our uranium and thorium supplies. They are fairly rare. But if we can use the whole of the element then nuclear energy becomes a practicable proposition, because then, in principle, considerably less than 100 tons of uranium or thorium would suffice, if we really used it efficiently, to produce all the power we want.

Of course, one day, if we ever learn to make hydrogen coalesce into helium, the heat will be a drug on the market. One pint of water, if the hydrogen in it could be made to combine to form helium, would give heat equivalent to burning 10,000 tons of coal—and there are plenty of pints of water in the world. Of course, that would produce a really colossal change, but we are a very long way from doing it. This is the way the heat of the sun and the stars is generated. It is the conversion of hydrogen into helium that produces the heat of the sun. A great many people say that as we have in the sun a nuclear furnace at a convenient distance, well shielded, and stable, we ought to try to use that. I agree. It might well be worth doing a good deal of work on trying to convert solar radiation into power. At present, unfortunately, apparently the best way of doing this seems to be to grow potatoes, turn them into alcohol, and burn that. But this uses only something like 1 percent. As I have said, all these things are a very long way off. But we have made great progress in the last 13 years.

Lord SAMUEL (closing the debate, said of Lord Cherwell's speech). I am particularly grateful to him for having, with all his wealth of knowledge, gone into the question of nuclear energy. I remember that when this subject was first mooted in this house, now some years ago, I had occasion to cross swords with the noble lord. I ventured to put forward the hope that within 10 or 20 years from that time the use of nuclear energy for purposes of industry and the production of power would be a practical proposition. I do not think it would be going too far to say that the noble lord at that time was very "sniffy"; his attitude was far more negative then than it is today. He says that in the last 13 years we have made great progress, and he holds out the hope that perhaps within a generation—I forget the exact term—the use of this unlimited source of mechanical power might come within the range of practical realization.

Lord CHERWELL. I hope that I did not give that impression. I did not suggest that the thermonuclear reaction turning hydrogen into helium would come within a generation to practical realization.

Lord SAMUEL. I was not referring to hydrogen, but to the sources now being used. Of course, if hydrogen were used, then nuclear energy would be available for every country everywhere, irrespective of national resources in coal, oil, or water supply.

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91. REMARKS BY GORDON DEAN, CHAIRMAN, UNITED STATES ATOMIC ENERGY COMMISSION, AT THE U. S. S. "NAUTILUS" CEREMONY, IN GROTON, CONN., ON JUNE 14, 1952

On behalf of the Atomic Energy Commission and its contractors, I want to say that we are immensely pleased and proud to be engaged with the Navy Department in this cooperative enterprise that you will see begin to materialize here today.

The propulsion of this submarine will be the first practical utilization of atomic power. To us, this will be a truly significant and gratifying event, for it will mean that atomic energy has been put to work not only as an explosive but as a fuel as well. The implications of this accomplishment, both for defense and for human welfare, are enormous.

The construction of the *Nautilus* has been made possible through many years of dedicated effort on the part of men of vision and enthusiasm in the Navy, the Atomic Energy Commission, and private enterprise. The roster of outstanding contributors includes the Navy's Bureau of Ships, the Argonne National Laboratory, the Westinghouse Electric Corp, the Electric-boat division of the General Dynamics Corp., and the AEC's Reactor Development Division. The atomic

submarine is an important concrete example of the kind of things that can be accomplished through a cooperative effort by scientists, industry, military men, and a civilian Government agency.

There are many people who have played a role in the events which have led to this ceremony; but, if one were to be singled out for special notice, such an honor should go to Capt. H. G. Rickover, whose talents we share with the Bureau of Ships, and whose energy, drive, and technical competence have played such a large part in making this project possible.

I deeply regret that Senator Brien McMahon, Chairman of the Joint Congressional Committee on Atomic Energy and author of the McMahon Act under which the atomic-energy program of this country functions, cannot be here in his home State today to participate in this ceremony. The confidence which Senator McMahon has shown in the future of atomic energy, the time and effort he has devoted to the cause of atomic development, and the personal interest he has long had in this project have been extremely valuable in lending impetus to its advancement.

This is a great day for the Navy, for the atomic-energy program, and for the American people. This submarine is going to work, and when it does work, it is going to be the forerunner of a new era, not only in naval warfare but in the history of mankind.

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92. AEC ANNOUNCES AIRCRAFT-PROPULSION PROJECT FOR REACTOR TESTING STATION

(U. S. Atomic Energy Commission, Washington, D. C., No. 438, July 29, 1952)

Construction of facilities related to the eventual development of nuclear propulsion for aircraft was authorized by the United States Atomic Energy Commission today. Testing facilities will be built at the AEC's national reactor testing station in Idaho.

The new facilities are estimated to cost approximately $33,000,000, and construction is scheduled to begin this summer, it was announced by AEC General Manager M. W. Boyer. During the peak of construction about 1,000 workers will be employed, and about 200 employees will be required for operations.

Preliminary design studies for the AEC ground test station have been performed by the Parsons-Macco-Kiewit Co., of Los Angeles, Calif., under a subcontract with General Electric.

The design, development, and fabrication of the prototype aircraft-propulsion reactor are being done by the aircraft gas-turbine department of General Electric at Lockland, Ohio. The nuclear phases of the project parallel the associated nonnuclear propulsion devices being developed by General Electric under an Air Force contract.

Design and construction of the ground test facilities will be administered by the AEC's Idaho operations office. The Chicago operations office will continue to have responsibility for the reactor-development contract with General Electric. Support in nuclear design and development also is being furnished by the Oak Ridge National Laboratory.

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93. DESIGN AND DEVELOPMENT OF LARGE SHIP REACTOR WILL BE CONDUCTED BY WESTINGHOUSE

(U. S. Atomic Energy Commission, Washington, D. C., No. 439, August 1, 1952)

Development work on a nuclear-power plant suitable for propulsion of large naval vessels such as aircraft carriers will be conducted by the Westinghouse Electric Corp., under a contract with the United States Atomic Energy Commission.

The existing contract between Westinghouse and the Commission has been modified to include work on the new project. The work will be centered at the Bettis plant, near Pittsburgh, Pa., operated by the Westinghouse atomic-power division. Other Westinghouse divisions and widespread subcontractors will assist.

94. AEC ACCEPTS PIONEER SERVICE AND FOSTER WHEELER PROPOSAL TO CONDUCT NUCLEAR-POWER-PRODUCTION STUDY

(U. S. Atomic Energy Commission, Washington, D. C., No. 446, September 14, 1952)

The Atomic Energy Commission has accepted a proposal by the Pioneer Service & Engineering Co. of Chicago and the Foster Wheeler Corp. of New York to conduct, during the next 12 months, a survey of the feasibility of design, construction, and operation by private industry of power-producing reactors. AEC and Pioneer Service–Foster Wheeler are now negotiating on details of the agreement.

The Pioneer Service-Foster Wheeler proposal is for a study similar to those which were conducted by four groups of firms last year. These were the Monsanto Chemical Co. and its associate, the Union Electric Co. of Missouri, both of St. Louis; the Detroit Edison Co. of Detroit, and the Dow Chemical Co., of Midland, Mich.; the Commonwealth Edison Co. and the Public Service Co. of Northern Illinois, both of Chicago; and the Pacific Gas & Electric Co. and the Bechtel Corp., both of San Francisco.

At the time that the agreements with these four groups were worked out, it was announced that consideration of additional proposals would be postponed. This was done to insure that the demands which would be placed on the technical personnel of the AEC and its contractors would be held to an acceptable level.

Upon completion of these first four studies, it was felt appropriate to invite other firms or groups of firms to participate in the reactor program under the same stipulations as were applied to the first-round groups. An announcement to this effect was made on April 6, 1952.

Six firms or groups of firms have responded. The Pioneer Service-Foster Wheeler proposal is the only one which has been submitted in sufficient detail for thorough evaluation to date.

Any agreement with this Pioneer Service-Foster Wheeler team or with other teams in the second round will follow the same lines as the first-round contracts. The main goals of the studies include—

(*a*) Determination of the engineering feasibility of design, construction, and operation of a reactor by private enterprise;

(*b*) Examination of the economic and technical aspects of building such a reactor;

(*c*) Measure of the research and development work needed before such a reactor project could be undertaken; and

(*d*) Recommendation to the AEC as to what should be the specific role of industry in carrying out such a reactor project.

As under present agreements, all costs on the first phases of these studies will be borne by the companies save for the cost of the time and effort of the AEC and its contractors. The AEC will decide on the distribution of reports and on the distribution of all inventions and discoveries made in the course of the work.

Security clearance will be granted, after investigation, to a sufficient number of qualified representatives of each firm or group of firms approved for activity in the second-round studies to carry out its survey.

It is expected that the Pioneer Service-Foster Wheeler study and any other survey contracts would run for 1 year.

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95. ATOMIC ENERGY

1952 atomic-energy policy of the American Federation of Labor as stated in the Annual Report of the A. F. of L. Executive Council and the official actions of the seventy-first convention held in New York City beginning September 15, 1952

I. REPORT OF THE EXECUTIVE COUNCIL TO THE CONVENTION

(Pp. 101 and 102)

Development of atomic energy in its various forms was gaining in importance in the life of the Nation, not only as a matter of self-defense and self-preservation but also as a source of yet unmeasured future productive peacetime growth. A large-scale construction program of additional facilities for production and

storage of fissionable products made up a large part of defense program of industrial plant expansion. It also brought the atomic-energy production within the ranks of major industries of modern America.

Under the Atomic Energy Act of 1946, the responsibility for directing the atomic-energy program rests with the Atomic Energy Commission, subject to a continuous and searching review by the Joint Committee on Atomic Energy of the Congress. This properly preserves the civilian charactcer of public responsibility for this vital program and makes possible close cooperation on policy between the legislative and the executive branches of the Government.

In view of the urgency to carry out the expansion of the program and in order to broaden the scope of civilian participation in the review of its progress and policies, the late Senator Brien McMahon, then chairman of the joint congressional committee, appointed on March 6, 1952, an advisory panel to advise and consult with the joint committee on the various phases of atomic construction and development. Lewis L. Strauss, a former member of the Atomic Energy Commission, is serving as the chairman of the panel, and the A. F. of L. is represented on it by Boris Shishkin.

The untimely death of Senator McMahon has delayed the organization of the necessary technical staff for the panel and the allocation of the funds essential for the study. The panel itself has already surveyed several new plant-construction sites.

Much of the progress of America's atomic-energy program is, for security reasons, necessarily veiled in secrecy. A large proportion of available and published information is so highly technical as to be an almost exclusive preserve of the scientists. All information that touches upon our Nation's security must, of course, be jealously guarded. But means should be found to enable the general public to know the issues involved in the atomic-energy policies and understand fully their implications. The ability of our Government to discharge this vital responsibility may, in time, become the test of representative government in a democracy.

Atomic energy itself and technology arising out of nuclear fission must remain in public domain. While development of private investment and enterprise for civilian use of atomic energy should be encouraged, such use of it by private enterprise should be strictly competitive. Private monopoly in any phase or segment of the atomic-energy industry is intolerable. Yet, even now monopolistic aggregates are already building up, not only around fringes of this public program but within it. Monopoly of engineering skill and scientific technology is no less dangerous than monopoly of private capital. No private corporation should be permitted to accumulate materials, equipment, or skill of this industry for its own exclusive use or to arrogate to itself the power derived from their exclusive possession.

We commend the step taken by the Joint Committee on Atomic Energy in appointing a public panel with labor participation. We urge that, in addition, qualified men, drawn from the ranks of labor, be chosen to serve on the Atomic Energy Commission and in appropriate posts within its organization.

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96. NEW AEC OPERATIONS OFFICE ESTABLISHED IN SAN FRANCISCO

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 448, September 17, 1952)

A San Francisco Operations Office of the Atomic Energy Commission has been established, General Manager M. W. Boyer announced today. John Flaherty, assistant manager of the Chicago Operations Office, is manager of the new office, which brings to nine the total of AEC's principal field administrative centers.

The San Francisco area office, which has been reporting directly to the AEC Production Division in Washington, and the Berkeley area office, which has been under the Chicago Operations Office, are consolidated into the new operations office, reporting directly to Dr. Lawrence R. Hafstad, Director of the Reactor Development Division.

The San Francisco Operations Office will be responsible for administration of contracts with the University of California for operation of the radiation lab-

oratory at Berkeley; the California Research and Development Co. for operation of facilities at Livermore, Calif.; the North American Aviation, Inc., for developmental work being conducted at Downey, Calif., and for other research and development contracts in the west coast area.

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97. ECONOMICS OF ATOM POWER

Walker L. Cisler, President, the Detroit Edison Co.

(Delivered by A. V. Griswold, assistant to the president, the Detroit Edison Co., before the Special Conference of the National Industrial Conference Board at the Waldorf-Astoria Hotel in New York City on October 17, 1952)

In a development as far reaching and significant as atomic energy may prove to be in industry, it is important that we endeavor to always keep our sights clear. The whole matter is extremely complex because much is yet to be known and understood concerning many phases of its progressive and systematic advancement.

Reactors for the production of large quantities of usable heat energy and other products are still in an undeveloped stage. The market and value of byproducts, such as plutonium and fission products, in the channels of commerce for civilian and military use are undefined. And certainly the matter of private industry in contrast to governmental development must be faced if the fullest efforts towards the solution of these manifold problems is to be accomplished. Consequently the economics of development of the atom for use in industry is admittedly a complicated one.

My efforts in this discussion will be devoted toward presenting some aspects on these problems with the hope they will prove helpful in bringing this part of the picture into perspective and balance.

In doing this I will use chiefly information, conditions, and conclusions developed in the joint project which the Dow Chemical Co. and the Detroit Edison Co. have been carrying on since March 1951. The first part of the discussion deals with the problems of electric power systems relative to supplying electric power to the public. The second part has to do with problems related to the type of reactor used as a source of heat, and the third part pertains to the role of private industry in the development of nuclear power.

ECONOMIC PROBLEMS OF ELECTRIC POWER SYSTEMS

It is generally agreed by private industry that the use of heat from nuclear fission can be economically justified only when the cost of heat from this new process is as low, or lower, than the cost with present conventional means. Proper credit, of course, must be given for byproducts, greater production, and other advantages which may result.

In the electric power industry the situation is quite clear. The problem is that of substituting a new source of heat energy for the heat energy now derived from coal, oil, and gas. There is a further problem concerning the energy from falling water, but this is a more complex problem and is not considered in this discussion. The economic question is: How can heat energy from a nuclear reactor be delivered to the point of utilization, the turbine generator throttle valve, at a cost equal to, or less than, the cost of heat energy from the conventional gaseous, liquid, or solid fuels now used?

Power systems supply capacity and energy—kilowatts and kilowatt hours—to their customers at rates which must be justified before and approved by public-service commissions. These kilowatt-hours contain the same amount of energy whether they are produced by present thermal electric stations using conventional fuels, by hydroelectric stations, or by the envisioned generating stations using the heat from nuclear fission. It is obvious, therefore, that power systems cannot justify the adoption of fissionable fuels, on a wide scale, until the costs are competitive with those of conventional methods.

In the Dow-Edison study the components of a large conventionable electric-power system, supplied by thermal generating stations, were carefully examined. The usual thermal electric generating station may be simplified into two parts, one having to do with the production and delivery of heat units from fuel and the other having to do with the generation of electricity. This same situation

would exist in the proposed generating stations utilizing the heat of nuclear fission. There might or might not be one added feature in that under some circumstances the nuclear plant might produce valuable byproducts.

This problem is illustrated by figure 1, which is a cross section of the St. Clair thermal power plant of the Detroit Edison Co., now under construction on the St. Clair River about 40 miles north of Detroit. This new plant will have four generating units with a total electric capacity of 625,000 kilowatts.

The shaded area represents that part of the plant concerned with the production of heat energy. Included are the coal- and ash-handling equipment, the boiler, flue-dust collectors, and stacks—all of the facilities needed to burn coal and deliver steam to the turbine generator throttle valve.

The unshaded portion of the plant includes the equipment and facilities needed to convert the energy in the steam received at the turbine generator throttle valve into electrical energy. These are the turbine generator, condenser, pumps, and numerous other equipment.

Estimates presented in figure 1 show the cost of the steam-generation facilities as $48 million, or $77 per kilowatt of capability. For electric generation the cost is $50 million, or $81 per kilowatt.

FIGURE 1

	Steam generation	Electric generation	Total plant
Total cost	$48, 293, 000	$50, 407, 000	$98, 700, 000
Cost per kilowatt capability	$77	$81	$158
Percentage of total plant	49	51	100
Percentage of total company investment	[1] 17	[1] 18	35

[1] These percentages represent the sum of the investments in steam-generation facilities, electric generation facilities, and power plants, respectively, in the 4 power plants of the Detroit Edison Co., as of June 30, 1951. The new St. Clair plant is not included.

These items are of particular significance. If a nuclear reactor is substituted for the steam-generation part of a modern thermal electric generating station, the part which would be eliminated represents a little less than one-half of the station's total cost. The part of the station used entirely for electric generation, costing just over one-half of the total for the station, must remain whether the heat source is conventional fuels or from a nuclear reactor.

There is no information available concerning the probable cost of a heat power reactor which might be used in a large thermal generating station. Recent published information gives the cost of the experimental breeder reactor at Arco, Idaho, as $2.8 million, excluding the cost of the site. This installation apparently has a capacity of about 250 kilowatts, or a unit cost of $11,200 per kilowatt. It is recognized that this is an experimental unit but it is readily apparent that its cost is many times that which can be justified for practical power generation.

A calculation was made in the Dow-Edison study by capitalizing, at 10 percent, the annual operation costs of the St. Clair power plant to determine the investment which might be justified in a reactor. It was assumed for the purpose of this calculation that the reactor would have no labor expense, no operating and maintenance materials and supplies expense, and no fuel costs chargeable against it. These somewhat idealistic conditions might be brought about by offsetting credits resulting from the production and sale of byproducts.

The calculation is shown in skeleton form by figure 2. The column on the left shows the estimated annual operating costs of supplying heat to the turbine generator throttle valve for the conventional plant. The one on the right shows the limit of the investment that could be justified in a reactor for these particular conditions.

FIGURE 2

Annual operating cost, St. Clair thermal electric power plant, 625,000 kilowatts capability		Justified investment in reactor—No labor, maintenance, or fuel cost (steam-plant annual operating cost capitalized at 10 percent)
$180,000	Operating manpower	$1,800,000
307,000	Operating and maintenance materials and supplies	3,070,000
	Investment in thermal plant	48,293,000
	Fixed charges on investment: *Percent*	
	Depreciation 3	
	Interest 5	
	Taxes and insurance 2	
4,829,300	10	
8,855,000	Fuel cost	88,550,000
14,171,300	Total	141,713,000
77	Investment per kilowatt capability	227
0.577	Cost per 1,000,000 B. t. u. at turbine throttle	0.577

For the shaded part of the generating station shown on figure 1 the operating manpower expense is about $180,000 a year, while the operation and maintenance materials and supplies expense is about $307,000.

The annual fixed charges on the thermal part of the plant—the part concerned with delivering the heat units up to the turbine throttle—calculated at 10 percent of the investment, amount to $4,829,300. The fuel costs for that plant will be $8,855,000 (1,233,000 tons of coal at $7.18 a ton). The total annual operating expense of the conventional plant is $14,171,300. The cost of delivering the heat units to the turbine throttle figures out to be 57.7 cents per million B. t. u.'s.

This is a significant item. It matters not to the turbine where the heat energy comes from so long as the proper steam conditions are maintained. It can come from gas; it can come from oil or coal; or it can come from fission of atomic fuel.

In the right-hand column the annual operating costs are shown capitalized at 10 percent. If it is assumed that the nuclear reactor has no operating labor expense, we can afford to invest $1,800,000 for that item alone. For operation and maintenance supplies and materials, we can afford to invest $3,070,000. The annual fixed charges on the investment in the thermal generation facilities, capitalized at 10 percent, are $48,293,000. If it is possible to get the equivalent heat units of the coal from the nuclear reactor at no fuel expense, what is normally paid for fuel can be capitalized at $88,550,000. The total of those amounts is $141,713,000—the amount which might justifiably be invested in a nuclear heat power reactor which, at no fuel cost and no operating labor or maintenance expense would deliver 1 million B. t. u.'s of heat energy at a cost of 57.7 cents. We would thus be justified in investing not more than $227 per kilowatt for a reactor and accompanying equipment capable of supplying steam to generate electric power.

Thus, a comparison of investment costs for two methods of supplying equal heat units to the turbine throttle can be made, in the thermal plant used in this study, $77 per kilowatt; in the atomic plant, $227, under the most ideal conditions. This becomes the limit within which we must work, because if the investment exceeds $227 per kilowatt, the cost of heat at the turbine throttle would be more than by the present conventional means.

There are several omissions in the determination which might be questioned such as profit, income taxes, and return on investment. In addition, there is no consideration of the fact that the reactor would be likely to have a comparatively short life. On the whole, however, the calculation does establish a reasonable limit for reactor cost. In systems other than that of the Detroit Edison Co., the $77 per kilowatt investment for the thermal plant might be different, and correspondingly dependent upon the operating and fuel costs, the $227 per kilowatt figure would be different. For example, in areas where the

cost is $9 per ton of 13,000 B. t. u. coal, and other factors were unchanged, the justified investment in a reactor would be about $260 per kilowatt.

If the ideal conditions, no fuel costs, no operating labor, no maintenance cannot be achieved, the justified investment in a reactor will be something less than $227 per kilowatt of capacity. With respect to fuel, Dr. Walter H. Zinn, Director, Argonne National Laboratory, in a recent article stated that for a breeder reactor, the cost of fuel is negligible. This statement is well founded and is referred to in greater detail later.

It is possible to evaluate the effects of operating labor, maintenance, and other probable operating expense on the justified investment in a nuclear reactor. All of the desired information concerning reactors which should be used in such an evaluation is not yet available.

It is recognized that a nuclear power plant has one possible cost factor not associated with conventional thermal plants, that is the exclusion-area requirement. Numerous methods are being explored and it is believed that it will be possible to prevent this factor from becoming a burden in the over-all cost of utilizing nuclear energy.

INFLUENCE OF TECHNICAL CONSIDERATION

In the Dow-Edison study technical conditions such as the types of reactors, the available fuels, chemical processing, and the byproduct situation were considered at length. All of these are closely related and have a most important relation to the long-range atomic energy development.

In recent issues of Nucleonics,[1] Dr. Lawrence R. Hafstad and Dr. Walter H. Zinn presented excellent analyses of several possible reactor types. We, in the Dow-Edison project, are in general agreement with their technical conclusions.

These analyses indicate that one simple class of reactors, if used for the production of heat would continually deplete the supply of naturally fissionable materials and would make effective use of only a small part of the total uranium fed to it. The available supply of naturally fissionable materials is not adequate for the widespread application of this type of reactor to electric-power generation.

A breeder reactor, as explained in the analyses of Drs. Hafstad and Zinn, would continuously produce amounts of fissionable materials in excess of that consumed. Thus, breeder reactors would augment rather than consume the world's supply of fissionable materials. Because this type of reactor indirectly burns the more abundant uranium 238 and thorium, the presently known nuclear-fuel reserves appear to be adequate for several hundred years for a large part of the world's power supply. Breeder reactors, since they produce more fissionable materials than they consume would supplement the operation of the AEC facilities at what we hope will be a lower cost than either our present Paducah isotope separation or Savannah River reactor installations.

There is no reason to refine further Dr. Zinn's assumption of a cost for uranium of $35 per pound. As each pound of uranium is equivalent in energy to 1,300 tons of coal it is apparent that we can generate about 2.6 million kilowatt-hours with each pound of uranium consumed. Thus, the cost for the fuel above for a breeder reactor is about 0.013 mills per kilowatt-hour, a negligible amount.

Our reports to the Commission included the following seven specifications. The reactor should—

1. Utilize low-cost fuel.
2. Have a high breeding gain.
3. Be a high-temperature machine.
4. Have an integrated processing operation.
5. Require a minimum of exclusion area, obtainable at low cost.
6. Have a simplified fuel element fabrication and loading.
7. Be inherently self-regulating.

We have used these specifications as the starting point in the second phase of our endeavor and have chosen what should be called a high-temperature breeder reactor, together with an integrated reprocessing scheme. This comprises a complete integrated reactor system which we believe most nearly meets the specifications.

The proposed reactor system is now the subject of detailed technical study. This is perhaps as subtle and difficult a problem as we could have set for our-

[1] Nucleonics, March 1952, The Future Reactor Program, by Dr. Hafstad. Nucleonics, September 1952, Basic Problems in Central Station Nuclear Power, by Dr. Zinn.

selves. There remains a large amount of research and development before such a reactor can become a practical, commercial reality.

We have considered that the cost of operating and maintaining the reactor, and of reprocessing the fuel, and of processing the excess fissionable material to be just equivalent to the revenue which will be received from the sale of the excess fuel which will be bred. This would fulfill the condition of no net charge for operating and maintenance costs. We hope eventually to do a little better than is indicated by this exact cancellation.

We doubt whether the first breeder reactor can be built within the cost of $27 per kilowatt, which earlier was shown to be the maximum investment that can be justified. We believe, however, that this may be possible after initial experience is gained.

It is obvious to all that the economics of atomic power are dependent to a large extent on future reactor developments with respect to types of fuel, by-products, and construction costs. Present indications are that these problems can be worked out in a favorable manner.

ROLE OF PRIVATE INDUSTRY IN THE DEVELOPMENT OF ATOMIC POWER

A discussion of the economics of atomic power would be incomplete without some reference to the role of private industry in its development. As could be expected, long and thoughtful consideration was given to the position of private industry in the development of atomic energy before our initial report was submitted to the Commission.

We are convinced that private industry can and should participate in the development. In fact, private industry should assume major responsibility for carrying forward the development of industrial applications of the heat of nuclear fission. Industry's talents are extremely widespread and industry is experienced in accepting development risks in order to save time. In this way industry moves forward rapidly. In government you must be right and you can afford to be right but you may be late.

In the early days of this country individuals—private industry—developed water power and created industries. When steam power became available, private industry expanded its operations and later created the vast electric-power industry which now spreads across our land. I do not know of a single industry important to us today that was not developed primarily by private industry.

With respect to atomic energy, the development will go forward in any event. The maximum benefits, and the greatest economic advances, will be provided for our country and for the world, however, only if private industry—private investment—is able to participate as they have in all of the great developments of the past.

There seems to be some question concerning whether private industry has the resources to carry the anticipated development forward. Information assembled by the Edison Electric Institute in September shows that the private electric-power systems plan to bring into service more than 28 million kilowatts of new generating capacity in the years 1952 through 1956, and at that time the plans for 1955 and 1956 were still incomplete. It is estimated that the cost of these generating stations will be approximately $4.8 billion. In addition, it is probable that more than double this amount will be invested in new transmission lines, substations, distribution systems, and other necessary facilities by these same electric-power systems. I am confident that adequate private resources are available to carry out the present requirements for the development of electric power from atomic energy and that the owners of these resources are anxiously awaiting the opportunity.

We are convinced that industry will participate to the fullest measure if it can do so in accordance with the free-enterprise system, if it has the opportunity to invest private funds and to enjoy the results of its efforts. This means that consideration must be given to certain legal aspects, particularly to those portions of the atomic-energy law which require governmental ownership of facilities and fissionable materials.

The approach of the Dow Chemical Co. and the Detroit Edison Co. to their joint project always has been that of private industry. They are proceeding with the second phase of their project as rapidly as possible. Progress has been greatly accelerated by the loan of experienced men from several other electric-power systems and industrial companies. If the technical problems can be resolved,

the two companies would like to build and to operate a commercial sized reactor plant using private capital and without recourse to governmental funds.

While it is recognized that the sale of byproducts is important, and even may be the controlling factor in a nuclear power plant, it is not considered at this time that a definite price for such byproducts established in advance, is necessarily a prerequisite for proceeding with this program.

It is expected that not only will there be a possible market for weapons purposes, but that there will also be a market for the excess fuel to meet the requirements for mobile reactors and for the requirements of an expanding nuclear power industry.

For the future, if we can achieve a flourishing private enterprise in the atomic-energy development, there should be a most important result. Our country's strength will be measured, not by the production capabilities of a Government arsenal, for this is indeed the great responsibility of AEC, but will be measured by the production capability of a great free enterprise, whose atomic products can be turned from civilian to military requirements at very short notice. Where would we be if our production of military trucks, or jeeps, or food, or clothing were dependent upon a Government arsenal? The material strength of this country is its flexible production capability, which is not a drain but a strength in peacetime, and a most vital asset in time of war.

The Atomic Energy Commission and the joint committee of Congress are fully aware of those problems and are giving the situation their most thoughtful consideration. It is certain that they know that decisions which they make will determine to a large degree the economics of the atomic-power development.

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98. ELEVEN COMPANIES TO JOIN DOW-DETROIT EDISON FOR JOINT STUDIES OF NUCLEAR POWER

(U. S. Atomic Energy Commission, Washington 25, D. C., No. 454, October 18, 1952)

The Atomic Energy Commission has announced that security clearances will be granted to the personnel of 11 companies which will become associated with the Dow Chemical Co. and the Detroit Edison Co. in their joint study with the Atomic Energy Commission for the development of a nuclear reactor to produce power. The 11 companies are—

The Cincinnati Gas & Electric Co.
The Cleveland Electric Illuminating Co.
Consolidated Edison Co. of New York.
Consumers Power Co.
General Public Utilities Corp.
New England Electric System.
Philadelphia Electric Co.
Public Service Electric & Gas Co. of New Jersey.
The Toledo Edison Co.
Vitro Corp. of America.
Wisconsin Electric Power Co.

Last April the Commission announced that it had accepted, in substance, a proposal from the Dow Chemical-Detroit Edison Cos. for a jointly financed research and development program for a type of reactor to produce fissionable materials and power. This is one of four groups which, for the past year, have been studying the feasibility of industrial participation in the reactor program. The study groups are—

The Monsanto Chemical Co. and its associate,
The Union Electric Co. of Missouri, both of St. Louis;
The Commonwealth Edison Co. and the Public Service Co. of Northern Illinois, both of Chicago; and
The Pacific Gas & Electric Co. and the Bechtel Corp., both of San Francisco.

Their final reports are now being examined by the AEC.

The investigations proposed by Dow-Detroit Edison are in keeping with the AEC's power reactor program and will intensify the approach to improved reactors along the lines selected. Most of the work by the two companies, estimated at about $275,000 in direct costs, not including overhead, will be carried on in their own laboratories. AEC research will be done in the special facilities

of the national atomic energy laboratories—Argonne at Chicago, Brookhaven on Long Island, and Oak Ridge. Much of the Commission's supporting investigation already is in progress or has been budgeted as a part of AEC's power reactor development program at about $725,000 in direct costs.

The associated companies will provide qualified personnel to carry on the work. In most instances, the men assigned to the project will have had previous experience in some phase of atomic energy problems. Each company will assign one or more men on essentially a full-time basis to work on the project and will function as if they were regular employees of either Dow or Detroit Edison. Security clearances will also be granted to a limited number of engineering and management executives of the associated companies who will add their background and experience to the project.

Other companies which can make a contribution to development work on the project may become associated with it. The AEC has reserved the right to designate or approve additional associated companies. The Dow Chemical Co. and the Detroit Edison Co., however, will remain the principal parties to the study agreement with the Commission. Should more companies than can be practically accommodated in the Dow-Detroit Edison project desire to join in such studies, they may affiliate with other existing study groups, or create new groups.

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99. THE PROSPECTS FOR ATOMIC-ELECTRIC POWER PLANTS

By Harry A. Winne, Vice President, General Electric Co., Schenectady, N. Y. Presented at A. I. E. E. Machine Tool Conference, Albany, N. Y., October 30, 1952

Please do not think I am going to give you a definite and precise answer to the questions implied by the title of this talk. I think the best anyone can do today is to speculate on the matter, but to me such speculation is interesting and I hope it will be to you. Let me hasten to add that I am not talking about financial speculation.

First, I had better make clear the bases for my speculation.

When I speak of an atomic-electric power plant, I mean a plant in which the source of heat consists of a nuclear reactor or atomic pile, in which heat is generated due to the fission, or splitting, of atoms of uranium or plutonium. This heat then generates steam or hot gas which in turn operates a conventional steam turbine or gas turbine driven electric generator.

Of course, it would be very nice if we could convert directly to electric power the energy released from the splitting atoms, but there seems to be no known or probable way of doing this, so we have to think of the atomic pile as essentially a steam generator, replacing the steam boiler and fuel and ash handling facilities of the ordinary fuel-fired power plant, with practically no change in that part of the station which is beyond the turbine throttle valve.

But, you may ask, do we know how to build such a power plant? From the technical standpoint, with perhaps just a little poetic—or engineering—license, my answer is yes. In fact, a very small experimental plant of this nature has already been operated, and two atomic-electric power plants for submarine propulsion are now under construction.

In all of these plants a liquid or gas flows in a closed circuit through the pile, picking up heat, and delivering it to a heat exchanger in which steam for the turbine is generated. There are lots of technical problems involved in the design and building of such a power unit, and we won't know whether we have solved all of them successfully until the units have been built, and operated for some length of time. I am sure we have, or will find, ways of solving them.

We know in general the kinds of materials that may be used. We know pile configurations that will work. We know how to control the power output of the pile. We know how to shield it to prevent danger to personnel.

But, we do not know how to build and operate it at a reasonably competitive cost. To solve that problem, I think, is going to take a long time, but I believe it will be done eventually.

As you probably know, there are four industry groups or teams which, under contracts with the Atomic Energy Commission, are now studying the economic possibilities of building atomic-electric power plants. Each group comprises at least one privately owned power company, and two of them include a chemical

company. These studies will undoubtedly result in some very worth-while information, but I fear will not provide the real answers to this basic economic problem. The Atomic Energy Commission has just announced an extension and expansion of this investigation.

I have not had the privilege of seeing any of the reports which have been developed, but I think undoubtedly that all of them contemplate an installation based upon an atomic pile which produces both plutonium for weapon purposes, and heat to generate power. This is perfectly practicable. In fact, the Hanford piles today produce plutonium and tremendous quantities of heat, although their design does not make it feasible to use this heat for power generation.

I would guess also that these studies will show that—based on any pile designs we know today—such installations could produce electric power at competitive costs only if the power is essentially a byproduct of plutonium production. Our Government is the only customer for plutonium at present, although perhaps other Governments would like to buy some. So, it seems to me, such plants could live economically only so long as the Government guarantees the market and price for plutonium.

In my opinion, this situation does not constitute a sound basis for an atomic-electric power industry. Certainly, barring war, at some time in the future our atomic-bomb stockpile should reach an adequately high peak, and the Government would not then be justified in continuing to purchase the plutonium output. It will probably be wondering what to do with its own plutonium and U–235 production plants. Atomic-electric power will be really economically sound only when it can compete with conventional electric power without requiring a Government-supported weapons market. It could not do that today—unless in some very peculiar and unusual circumstances—nor, in my opinion, for a good many years to come.

Accurate cost comparisons are impossible because of the secrecy which surrounds data on atomic piles. A couple of years ago an Atomic Energy Commission paper stated that the average cost of then planned experimental piles was on the order of $10,000 per equivalent electrical kilowatt output. Presumably the knowledge which has been gained in the past 2 years would permit reducing that considerably, particularly for a large-capacity unit such as would be used in a big central station.

However, in addition to the reactor and heat-exchanger system, there may be needed an expensive chemical plant for reclaiming what may be termed "partly burned fuel." On the other hand, perhaps reactors can be designed in which so much of the available fuel in the charge can be burned—or more correctly, fissioned—that it will not be worth while to try to rework the material discharged from the pile. Installations expensive to build and operate may, or may not, be needed to prepare the fuel charges. (You can see why I said I could only speculate on the future of atomic-electric power.)

If I could get reasonable odds, I would bet that for this power plant of the long-term future, we would get along without the chemical plant for reclaiming fuel from the ash, but that the preparation of the fuel would be a fairly expensive process. This is just a hunch, nothing more.

As to the cost of present day conventional fuel-fired plants, some interesting cost figures are given in a paper by Mr. Walker L. Cisler, president of the Detroit Edison Co., presented at the University of Michigan Law School June 26, 1952. He states that in a 625,000 kilowatt coal-fired station now under construction, the cost of the electrical part of the station, including the turbine generators, is $81 per kilowatt capacity, while that of the steam generating part of the station, the counterpart of the atomic pile and heat exchanger, is $77 per kilowatt.

That gives you an idea of the target. I think we do not yet have the gun nor the ammunition to come anywhere near hitting it. But just give us time—and quite a lot of it. I feel we need time more than we need money—time for knowledge to be gained; time, we might say, for a favorable "climate" to develop. This matter of what, for lack of a better term, I call "favorable climate," is of great importance. It involves a number of factors, not alone scientific and engineering knowledge of materials and physical phenomena. It includes experience, built up as we progress from one step to another. It includes scientific, engineering, and manufacturing tools, some developed in this project, some in projects far afield. It includes the attitude and receptivity of the public.

Tremendous expenditures by the Government, or by private industry, can accelerate remarkably the development of a "gadget" such as the atomic bomb, or an experimental atomic-electric power plant, and such adventures of course

help to build up knowledge and experience, but I think we cannot greatly reduce the time cycle required for the economic development of such a fundamental industry as atomic-electric power.

Let me illustrate the reason for this belief by citing the case of the gas turbine. The fundamental theory of the gas turbine was well known before the turn of the century. But, to make it practical, metallurgists had to develop new high temperature alloys, engineers had to gain new aerodynamic knowledge in order to design turbines and compressors of adequate efficiency, manufacturers had to develop new methods of machining and fabrication. If the production of an operating gas turbine 50 years ago had been a command performance—as was the manufacture of an atomic bomb in the early forties—the expenditure of billions of dollars would probably have resulted in a working unit, perhaps with combustion chambers and buckets of platinum. Imagine what its cost might have been.

But an economical unit could not have been achieved then, nor for many, many years. Fifty years ago the necessary knowledge of materials and fabrication was not available. More than that, the tools to develop this knowledge were not in existence. There were no industrial X-rays, no spectographs, no stainless steels, no arc welding equipment, no electric furnaces. Some of the metallic alloying elements we use today had not even been discovered. These are all part of the "favorable climate" required for sane, economical development of the gas turbine.

What new tools and new knowledge do we need in order to build economical atomic-electric power plants? I don't know, but I am reasonably sure we shall find them in the decades, and I mean decades, to come.

Perhaps I am pessimistic, but I have an uneasy feeling that it is unfortunate that our entry into the atomic energy era was by way of the atomic bomb—and when I say that I am not thinking at all of the use of the bomb. It seems to me we may have entered the development path at the wrong end. Again, let me illustrate, in an endeavor to make clear what I mean.

Suppose that, for some compelling reason, in the very earliest days of the transformer, an all-out effort had been made to build a 220,000-volt transmission system. At tremendous expense it might have been done, but can you imagine what the transformers, the switchgear, the insulators, would have looked like? Then, to go from there to our present stage of development, it would have been necessary to work back down the path of development. We would undoubtedly have developed groundless fears, which would need to be dissipated. We would have developed a lot of outlandish factors of safety. We would probably have been somewhat unduly appreciative of our success, and overwhelmed by our seemingly great store of knowledge.

Could it be that we are in a somewhat similar situation in the atomic energy field?

Most people undoubtedly feel that atomic energy development is so vastly expensive that it would not have come about unless Government undertook it. We certainly would not have had the atomic bomb, nor submarine power plants, at present dates without Government financing. But I am not at all sure that we shall have a sound atomic-electric power industry appreciably sooner than we would have if this development had taken a more normal course in the interested private industries. Of course, that is a perfectly safe statement for me to make, for it can never be proved to be incorrect, or correct.

In the consideration of a possible future atomic electric power industry, one question which always arises is as to the availability of nuclear fuel. A great share of the uranium used in the Western World at present comes from the Belgian Congo. However, natural uranium is pretty widely distributed throughout the earth, though most of the deposits are low grade. Workable deposits have been found in the Colorado Plateau and in Canada. There are substantial quantities in the tailing piles of the South African gold mines. Phosphate rock in Florida offers a possible source, although the concentration of uranium is low.

Of course, fissionable uranium 235 constitutes only 0.7 percent of natural uranium, but it seems probable that the processes known as conversion, or breeding, carried on in an atomic pile at the same time it is producing heat for power purposes, will ultimately make it possible to convert a large part of the 140 times more abundant uranium 238, and still more abundant thorium, to fissionable material. Phosphate rock may contain from 0.2 to 0.4 pounds of natural uranium per ton of rock. About 1 million tons of this rock is used per year for wet process phosphoric acid production from which is seems feasible to extract

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uranium. A great deal more is used for the production of superphosphate. If we assume that this 1 million tons has an average of 0.3 pound of uranium per ton and that we could recover economically two-thirds of this, we would have 200,000 pounds of uranium. Now assuming that through breeding and conversion, we are able to utilize half of this, namely, 100,000 pounds, as atomic fuel, we have the equivalent in heating value of 150 million tons of coal, or about 20 to 25 percent of our present annual usage of coal.

So you can see, assuming that we can make all of these assumptions come true, and I admit that this is compounding assumption on assumption, we have the possibility that atomic fuel may prove a welcome addition to our over-all fuel supply in the long term future. Of course, I am not talking about the present nor the immediate future, but rather several decades from now. Let us not start to close down the coal mines. Atomic energy, in my opinion, will only supplement, and not supplant, our present fuels.

Another question which must be considered is whether atomic electric power plants can be reasonably free from the rigid governmental control which now exists. I think they can be. Under present conditions, with practically all of the country's production of atomic fuel going into bombs, and with such emphasis on secrecy, it is obvious that the Government will retain complete control of all reactors. Even so, it could sell to utility companies any electricity generated, or even steam, or heat in some other form.

But I cannot conceive that present conditions will continue for very many years. There must be a limit to the useful size of a bomb stockpile. Our potential enemies will, in time, probably know as much about atomic energy as we do—possibly even more. So the need for extreme secrecy may disappear.

If and when atomic bombs become as common and widespread as TNT and other munitions, I see little chance for effective international control of atomic energy. If we are smart enough to find a means for preventing all war, then international as well as national control may become unnecessary.

So, at some time in the future I visualize the opportunity for the Government to discontinue its major operations in this field, and to permit private industry to forge ahead. I cannot forecast whether or not our Government will wish to take advantage of this opportunity.

I hope that the Atomic Energy Commission and the Congress will soon begin to consider thoroughly steps which might be taken—without in any way jeopardizing national security, of course—to relax some of the stringent restrictions to the present Atomic Energy Act. An evidence of some activity looking toward this end, would, I think, greatly stimulate industry's interest in the whole atomic energy project.

Now let us consider some possible applications of atomic-electric power plants. An important determining factor is the great concentration of energy in nuclear fuel.

The submarine seems to offer an ideal application, and it is probable that the first practical application of atomic-electric power in this country will be to a submarine power plant. Both the General Electric Co. and the Westinghouse Electric Corp. are designing and building such plants for the Navy. The land-based prototype of the General Electric equipment is being erected on a site at West Milton, N. Y., about 18 miles north of Schenectady.

The concentration of energy in atomic fuel is so great that it seems probable that the initial fuel charge would be sufficient to permit the submarine to operate for a number of months without requiring additional fuel. Furthermore, atomic fuel does not require combustion with air to liberate its energy. Therefore, a submarine should be capable of operating submerged at full power and for very long periods of time. This would of course be a tremendous tactical advantage.

As you also know, the Air Force is very actively interested in the application of atomic power to aircraft, and both the General Electric Co. and Pratt & Whitney are working on this application.

While the light weight of the fuel, and the long range which it would permit, are great advantages, the necessity for heavy shielding is a distinct disadvantage, and so this application involves very difficult scientific and technical problems.

The heavy shielding required and the complicated heat transfer system preclude any possibility of application to automobiles or similar vehicles. It may be possible some day to build an atomic power plant for locomotive application, but I question whether it will be economical. Because nuclear fuel is such an extremely concentrated source of energy, atomic energy may bring economical electric power to areas where the transportation costs on ordinary fuel are

extremely high, before it comes into more general use. However, I do not visualize small atomic power plants springing up in every isloated area. To be efficient and economical I think an atomic power plant will necessarily be of large capacity, perhaps at least a hundred thousand kilowatts, except perhaps for military or other very special situations.

The four studies involving the proposed reactors combining power and atomic fuel production, which I mentioned previously, are indicative of an increasing interest by industry in the atoimc energy field. Activity in the AEC program on the part of many other industries acting as contractors, such as du Pont, Carbide & Carbon Chemical, Monsanto, Westinghouse, General Electric, to mention only a few, while dictated to a considerable degree by patriotic motives, also indicates a very healthy interest which I hope will grow. Only thus can we learn to build better and less costly atomic power plants which I believe in the long term future will make atomic energy a significant contributor to our industrial activity.

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100. THE GUARDED PEAK

An interview with Dr. J. Robert Oppenheimer by John Dos Passos

(From This Week Magazine, New York Herald-Tribune, November 2, 1952. Reprinted by permission.)

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"How much is atomic energy going to change the shape of our society?"

"You mean peacetime applications?" he cries out, as if the question had brought his thoughts back from the painful channels to something innocent and friendly, a baby's prattle breaking incongruously into a conversation about death. "Of course there are possibilities for its use on ships and to generate power in places where coal and oil are lacking, atomic plants. * * * I'm hoping we'll soon try some remote power stations and begin to get our feet wet in the problem. The trouble is that the atom for war so outweighs the atom for peace. That's what I I was thinking of. The destructive possibilities of our technology had already outrun any humane control. It is a very worrisome thing. It is highly ironic that science should come up with atomic energy at a time of such deep conflict and such pervasive threats of war."

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101. WANTED: SMALLER AND MORE REACTORS

By Alvin M. Weinberg, Director of Research, Oak Ridge National Laboratory

(From Nucleonics, November 1952. Reprinted by permission of Nucleonics Magazine.)

Of the many problems which make the establishment of a bona fide nuclear energy industry difficult, I think the most serious stem from our "nuclear megalomania." We have been conditioned to think of nuclear installations as multi-hundred-million-dollar enterprises. In seeking a way to bring nuclear reactors into the usual channels of competitive industry, we have therefore naturally turned—as in Mr. C. A. Thomas' well-known proposal—to combination plutonium plus power systems. To produce plutonium economically and at the same time make power at 5 mills per kilowatt-hour or so, these systems must necessarily be enormous.

For the present the number of $150 million reactors which even our country can afford is small. As a result, our nuclear energy technology consists mainly of a very few very large projects. Because the technology depends on so few separate entities, it is hard to inject into it the kind of developmental flexibility which characterizes, say, the automobile industry. Risks are hard to take, and the demand for AEC subsidy of the risk is perfectly understandable, especially since AEC is the only customer. As long as there is only one customer who also pays all the development bill, it is idle to try to impress the cast of traditional private industry on nuclear technology.

In every other major technology—airplanes, power, hydraulics, bridge building, architecture, even rockets—the art has developed from small, simple, and relatively cheap devices to large, complicated, and expensive ones. These industries, in contrast to nuclear technology, have therefore been able to depend on a whole size spectrum of gadgets. This size versatility has given flexibility to these developments; it has made it possible for each technology to generate a comparatively broad consumer demand for its many different products.

To some extent, the reactors for military propulsion—the STR, SIR, and aircraft—will help to reduce the scale of each step in our nuclear development that it now possesses. However, the military reactors, as articles of commerce, suffer from the usual difficulty that in a military framework economic considerations tend to be abrogated. Military reactors, as other military devices, always must pay a price for the time that they buy.

There is another area of nuclear reactor development, however, which could rather soon be put on an economic basis, and which I regard as an attractive alternate to the colossal plutonium-plus-power schemes as a way for industry to get a start in nuclear energy. I refer to Mr. L. R. Hafstad's recently reiterated suggestion of small, cheap nuclear power packages for use in remote localities where power is now very expensive.

There must be a substantial number of places within United States jurisdiction which could use blocks of power of a few thousand kilowatts at a price of 3, 4, or perhaps, in some cases, 5 cents per kilowatt-hour. I believe it ought to be possible to take the experience gained from the ship reactor projects and, by rationalizing designs, to come up with a relatively cheap nuclear power package in the 5,000-kilowatt (of electricity) class, with installation costs of the order of $500 per kilowatt, and power costs between 2½ and 4 cents per kilowatt-hour. If there were even 50 locations where such power packages could be used economically, supplying these devices might develop into a spirited, flexible, $150 million business which would not be dominated by any single Government agency.

The major problem in any such scheme is, of course, the allocation of fissionable material. However, as Mr. Gordon Dean indicated in his recent San Francisco speech, we will in the foreseeable future be entering a period where the demand on fissionable material for bombs ought to be more than met, and there will be extra U–235 or Pu–239 left over for power purposes. I would imagine that many of the customers for such out-of-the-way power plants might be Government or quasi-governmental agencies whose requirements for power and, therefore, U–253, might be justified, as is the Navy's, by the needs of national defense.

The design of such a power package would have to depend strongly on experience with, say, the STR. Some regeneration of fuel would certainly be desirable. As Mr. Zinn said in the September 1952 Nucleonics, the fuel cost would be 1.3 mills per kilowatt-hour if a conversion ratio of as little as 0.8 could be achieved. However, the figure of between 2½ and 4 cents per kilowatt-hour ought to be achievable even without fuel regeneration.

The main advantage of the power-package approach to establishment of a nuclear energy industry is that the technology would rely on comparatively many small units, rather than on a very few enormous ones. Thus, industry would not try to hit the jackpot right off, but would edge into the business a little at a time and at each stage would be able to match its risk with its financial capability.

It seems to me that Nucleonics could do the infant nuclear energy industry a very real service if it carried out a survey to determine just how big the market is for, say, 3-cents-per-kilowatt-hour electricity. There are perhaps a dozen working groups throughout the country who, once they were convinced of the existence of a market for nuclear power packages, might set to work trying to design the best such package. I hope that out of such competitive effort, centering on these small power packages, might come the beginning of a real, vigorous nuclear power industry.

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102. THE EDITORS HEAR * * *

(From Nucleonics for November 1952. Reprinted by permission of Nucleonics Magazine.)

In an interview with Nucleonics, AEC Chairman Gordon Dean said: "AEC may not be able to guarantee a plutonium market to builders of industrial power reactors."

It isn't wise for AEC to build a pilot power reactor such as has been proposed by some companies. He says that if AEC builds anything—and he says it should soon—it should be a full-scale power unit.

The AEC commissioners are all agreed that at least one small "power package" (10,000 to 50,000 kilowatts) reactor generating station should be built within the next year. Dean feels two such reactors should be built. He says they should be in remote, high-cost power areas at Government installations rather than private ones (this would seem to eliminate the proposal of the Eureka, Nev., mining group—NU, September 1952, p. 66).

The fact of the detonation of the British atomic bomb last month does not change matters as far as exchange of information between this country and England is concerned. However, Mr. Dean feels that if we are to be full military partners with England atomic energy information should be shared as part of such a partnership.

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103. ATOMS AND ELECTRICITY

THE BRITISH MAY BEAT UNITED STATES TO COMMERCIAL ATOMIC POWER OUTPUT—UNITED KINGDOM'S ELECTRIC SHORTAGE WILL JUSTIFY START OF HIGH-COST PROJECT WITHIN YEAR—STATUS OF DOMESTIC PLANS

By Ray Cromley, staff reporter of the Wall Street Journal

(From the Wall Street Journal, November 7, 1952)

WASHINGTON.—Prediction: Britain will beat the United States in building the first atom plant to supply commercial power to industry.

The British plant will probably start going up within the next year. It will be at least 2 years or more before a commercial United States plant is started, atom experts in industry and Government say. Most of the latter and many of the former agree that as a result United States commercial power production from atom fuels will lag behind British output for some time.

It will likely be 4 or 5 years before the British plant is finished and selling power. It will be a large undertaking—somewhere between 150,000 and 250,000 kilowatts of generating capacity. By way of comparison, the largest conventional steam electric-generating plant in the world, on order for TVA, will have a 250,000-kilowatt capacity.

Experts predict the British plant will supply commercial electric power at about 1½ cents a kilowatt-hour, which is competitive with conventional power plants being built these days in Britain. Such a cost, however, is a lot higher than the cost of producing power in the United States. Here, a cost of over one-half cent a kilowatt-hour is considered high.

BOMBS AND POWER

The British plant will be a dual-purpose atom power plant. That is, it will make plutonium for sale to the British Government for making atom bombs and it will, at the same time, produce electric power to sell commercially to British industry.

It is not certain yet whether the plant will be built and operated by the British Government or by private industry with heavy Government investment and control.

Why the United States lag?

It's not because United States atom-power research is behind Britain's. It isn't.

One major reason for the lag: It's going to take United States Government officials a year of discussion, they estimate, to settle some thorny Government economic, moral, and security questions before letting the atom loose to private industry.

The Atomic Energy Act itself would probably have to be changed, though it's too unclearly worded to say for sure. But Atomic Energy Commissioners understand that it was the intent of Congress to make production of fissionable materials a Government monopoly. And these materials would be produced in atom-power plants as part of the power-making process.

The coming change of administration in Washington is another of the uncertainties surrounding United States A-power production. President Eisenhower and his appointees may have some ideas of their own on the subject. But by

and large the Atomic Energy Commission is one of the least political of the Washington bureaus.

When the United States does get going, it's expected to go slower than the British in the development and consumption of atom power. Because ordinary commercial power is so cheap in the United States (and new commercial power is so expensive in England, it will be easy for atom-produced power to complete with ordinary power in England—and difficult for atom-produced power to compete in the United States except in isolated places.

POWER FOR UNITED STATES MINES?

So atom experts here predict the big drive for commercial atom power in the United States will be for mines (like gold mines) in isolated spots where it's too expensive to ship in coal or put up ordinary long-distance power lines.

But already, several conservative American companies are said to be ready to operate commercial power plants, if the Government gives them a go-ahead sign. Though a great hush-hush aura envelops anything connected with this subject, it's known which firms are experimenting in this field, and have made proposals to the Government.

Detroit Edison Co. and Dow Chemical Co. are going ahead with a joint research project with the Atomic Energy Commission on a better reactor. Monsanto Chemical Co. and Union Electric Co. have jointly proposed building a pilot plant.

Two other groups have made recommendations for building and operating plants—Commonwealth Edison Co. jointly with Public Service Co. of Northern Illinois, and Pacific Gas & Electric Co., together with Bechtel Corp., both of San Francisco. Union Carbide & Carbon Corp., which operates the Oak Ridge atomic installations, is also developing reactors.

PROPOSALS STAMPED SECRET

AEC men say they have these proposals in their files. They're marked secret, however, both as to what they propose, and as to which firms have made exactly what specific proposals.

But in General, Government atom officials say, private power men suggest that if the United States will sell them enriched uranium (ordinary uranium spiked with a greater-than-normal amount of the scarce radioactive kind of uranium atoms) at a mutually agreeable rate, and buy—also at such a rate—the plutonium (material for bombs) which atom power plants would turn out as a byproduct, then they'd like to produce power to sell commercially.

The Government atom men say that these private proposals are economically fair. They propose a rate for plutonium that's pretty close to what the Government figures is a fair price.

But while private power men are willing to gamble on commercial atomic power, the Government isn't as yet. There are several reasons.

PRICE AND TIME

The price at which these proposals reportedly would require the Government to guarantee to buy plutonium for bombs would be high—albeit fair for what the Government would be getting. What's more, the Government would be required to buy plutonium at this price for many years, probably around 20 years or more.

The atom men aren't at all certain the Government will want to buy plutonium in large quantities for such a long time. They think maybe we'll have all the stockpile of A-bombs we need well before then.

The Government has not yet figured out any way to let some companies build and operate atom power plants without giving an unfair advantage to these companies. Government atom men point out that the public has made a big investment in atom energy—and say that this public investment must be protected. They're afraid some companies might profit unduly from this public investment.

HEALTH AND SECRETS

Federal officials are worried also about how to protect atom secrets in such commercial plants, how to guarantee the health of private workmen against radioactivity (since there are no laws covering these hazards), and how to

guarantee Federal control over all bomb materials produced in private plants.

Then, too, Government atom men think it might be better all around to delay building atom power plants right now. They figure that atom power plant design is in its infancy—that there'll be big improvement within the next year or two.

"So why," asks one expert, "encourage the building now of a plant that would become obsolete rapidly, when we can wait? We're not facing a power shortage, so speed isn't critical."

At present, it isn't clear whether the proposals before the AEC suggest that private industry would build the atom power plants, or whether they propose the Government build them and then lease the plants to private industry.

SOME POSSIBILITIES

Some indication of the degree of secrecy surrounding the matter of who will build the plants: An official of one company involved in atom power, after securing a solemn commitment that his name wouldn't be used, declared: "We don't know."

However, there were three possibilities referred to at a recent meeting of the National Industrial Conference Board:

1. A Commonwealth Edison-Public Service plan was outlined which "might" be used by a privately owned utility. This envisioned a dual-purpose atomic reactor built by the Government on a site also including electric generating equipment built by the utility. The utility would operate the plants, would buy heat for electricity output from the Government at a cost equal to conventional fuel costs.

2. A Detroit-Edison plan—the utility "prefers to own the atomic energy facilities and do what we think best with due regard to security."

3. Outright Government ownership of power-producing facilities such as the Interior Department's present operation of certain power units.

BRITISH AND PRESTIGE

The British atom power plant building plans are as secret as the American. But apparently the British Government is much more in a hurry than the American Government. So it will hurdle the roadblocks faster.

The British are in a hurry not only because their new conventional power plants produce such expensive power, but they're in a hurry for prestige reasons, too. They want to be first in commercial atom power, as they were first in producing first-class commercial jet planes.

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104. ANNOUNCEMENT OF APPOINTMENTS

United States Atomic Energy Commission, Washington 25, D. C.,
November 10, 1952

Effective August 15, 1952, Brig. Gen. Donald J. Keirn of the United States Air Force has been appointed to the position of Chief of the Aircraft Reactors Branch, Division of Reactor Development. In addition to his assignment in the Reactor Development Division, General Keirn will also serve as Assistant for Aircraft Nuclear Propulsion to the Commanding General, Air Research and Development Command, Baltimore, Md., and as Assistant for Aircraft Nuclear Propulsion to the Director of Research and Development, Deputy Chief of Staff Development, Headquarters USAF. This will provide a central programing authority to make possible a more effective use of combined Air Force and AEC management and administrative talent in conducting the important program for aircraft nuclear propulsion.

General Keirn was formerly with the Manhattan District and the AEC during the period from spring 1946 to July 1949. It was during this time that the formative phases of the program were under way. General Keirn is well known for his work in the Air Force as a principal contributor of pioneering effort on the development of the gas turbine engine for aircraft propulsion. At the direction of Gen. H. H. Arnold (then Chief of the Air Force), General Keirn administered the first jet engine experimental work undertaken by the Air Force. General Keirn is located in room 309, x–512. Col. Ralph L. Wassell, USAF, who has been serving as Chief of the Aircraft Reactors Branch in its control of the AEC part of the ANP program, will now serve as deputy to General Keirn in the combined AEC–USAF ANP program.

Col. James B. Lampert of the Corps of Engineers has been detailed as liaison representative of the Department of the Army with the Division of Reactor Development. Colonel Lampert will be studying the possibilities of using energy from nuclear reactors to fill certain Army requirements for electric power. This cooperative Army-AEC effort is designed to determine for the Army the exact nature of requirements that might be filled by electric power produced from atomic energy sources, as well as the nature of reactor designs most suitable for this purpose. In this assignment Colonel Lampert will report to Lt. Gen. Lewis A. Pick, Chief of Engineers.

Colonel Lampert has served previously in the atomic energy field, first as executive officer for Lt. Gen. L. R. Grove, head of the wartime Manhattan project, and later as special assistant to Maj. Gen. K. D. Nichols, Chief of the Armed Forces Special Weapons Project. Colonel Lampert is located in room 313–A, x–601.

Dr. Robert P. Petersen has been appointed Chief, Industrial Power Branch, Division of Reactor Development, effective November 24, 1952. In this position he will be responsible for the Branch's program to support industrial interest and participation, particularly on a risk basis, in the reactor development program. He will also direct certain reactor development projects aimed at obtaining economical electrical power for industrial purposes.

Dr. Petersen comes to us from the Sandia Corp., Albuquerque, N. Mex., where he has served as director of research since 1949. Previously, he was a physicist on the staff of the Applied Physics Laboratory of Johns Hopkins University. His Ph. D. in physics was received from the University of California in 1946. Dr. Petersen will be located in room 311, x–364.

LAWRENCE R. HAFSTAD,
Director of Reactor Development.

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105. NUCLEAR ENERGY AS A SOURCE OF POWER

Presented before Washington ASME, November 13, 1952, by John W. Landis, Reactor Development Division

Nuclear energy is not new. It has been aiding and abetting life on this planet since the first spore was either accidentally or purposefully created by some unknown chemical reaction eons ago. I mean that the energy we *have* lived by and *are* living by today—heat and light from the sun—is nuclear in origin.

It all comes about because the sun (in reality a medium-sized star) comprises such a tremendous agglomeration of matter that its gravitational force is sufficient to squeeze its own interior to great pressures and extremely high temperatures. Under these conditions nuclear reactions are as commonplace as chemical reactions are on the earth. The nuclear reaction which is responsible for most of the sun's energy is believed to be a transmutation of hydrogen to helium, with carbon–12 acting as a sort of "nuclear catalyst," as follows:

1. Carbon (12) captures hydrogen (1)→nitrogen (13)
2. Nitrogen (13) breaks down→carbon (13) and positron
3. Carbon (13) captures hydrogen (1)→nitrogen (14)
4. Nitrogen (14) captures hydrogen (1)→oxygen (15)
5. Oxygen (15) breaks down→nitrogen (15) and positron
6. Nitrogen (15) captures hydrogen (1)→carbon (12) and helium (4)

We use the radiation from the sun as it comes to us each day, but we are not satisfied with just this amount. We continuously extract from the earth in the form of coal, crude oil, and natural gas the stored-up products of yesterday's sunshine. We also make use of the potential energy which solar heat has transmitted to the water in the atmosphere; we turn our turbines with this water as it rushes off the land slopes back to the sea.

The latter source of energy is a renewable one; coal, crude oil, and natural gas are not. Yet, coal, crude oil, and natural gas (the so-called fossil fuels) supply the bulk of our power needs today. The question which immediately arises, then, is, "How long will these fossil fuels last?"

The answer to this depends, of course, on two factors: (1) What quantities of these materials are recoverable from the earth; and (2) at what rate are they being and will they be consumed?

The ultimate reserves of coal, crude oil, and natural gas have always been subject to much argument and conjecture. Because discovery of each continues

at an unpredictable pace and because methods of extraction and utilization are constantly being improved, one can never be quite sure that an error of some magnitude has not crept into the calculations. For the purposes of this talk, I have selected what I believe to be fairly optimistic figures for these reserves.

As for the second factor, I have adopted the policy of Palmer C. Putnam, who made a study on fuel availability for the Division of Reactor Development, that the logical approach to estimating future fuel consumption is one which takes into account both the growth of the world's population and the probable increase in demand for power per person.

You have probably already guessed that what I am going to try to show with these data is that our conventional fuels are being used up at an alarming rate and that it may be necessary to draw upon nuclear fuels for power in the not-too-distant future. You may not have guessed that I am also going to try to prove that in addition to the need for the development of nuclear power plants which the impending depletion of conventional fuels has occasioned, there may be an economic advantage to nuclear power.

Now—as you undoubtedly realize—I am referring to man-made nuclear power plants which, in contrast to my opening statement, are new. They are new largely because they employ a new-type firebox called a nuclear reactor. A nuclear reactor is a device to initiate, maintain, and control a fission chain reaction and thereby release the resultant energy gradually, not explosively. The result is heat—lots of it. When I finish discussing the desirability of developing reactors I shall describe them for you.

CONVENTIONAL FUEL RESERVES

Weeks and Moulton have estimated that the world's ultimate production of crude oil will total 610 billion barrels. Since 62 billion barrels have been produced to date, the present reserves approximate 550 billion barrels. In terms of a common denominator which may be used to indicate the comparative abundance of all fuels, this reserve represents 35×10^{17} B. t. u.

Supplementing crude oil are two other sources of liquid hydrocarbons: (1) Natural gasoline (liquid hydrocarbons extracted from natural gas) and (2) shale oil. Assuming a ratio between world supplies and United States supplies equal to that for crude oil (as given by the American Petroleum Institute), reserves of the former total 11.5 billion barrels and reserves of the latter total 620 billion barrels. These amounts represent 0.74×10^{17} B. t. u. and 40×10^{17} B. t. u., respectively.

Again assuming a ratio between world supplies and United States supplies equal to that for crude oil, and taking the base figure for the United States as 180 trillion cubic feet (American Gas Association), reserves of natural gas total 560 trillion cubic feet, of 6.0×10^{17} B. t. u.

The energy residual in the world's reserves of oil and natural gas, therefore, is approximately 82×10^{17} B. t. u. Let us see how this compares first with the energy residual in coal and then with the energy residual in uranium and thorium, our two nuclear fuels. All these figures are as of January 1, 1950, incidentally.

According to Dr. Arno C. Fieldner, Chief of the Fuels and Explosives Division of the United States Bureau of Mines, the recoverable reserves of coal in the earth's crust total 3,482 billion tons. This vast lode represents 72×10^{18} B. t. u., or almost 10 times the energy residual in the oil and natural gas reserves. Thus, coal comprises the bulk of our conventional fuel reserves.

NUCLEAR FUEL RESERVES

The best guess today concerning the amount of recoverable uranium in the world is 25,000,000 tons. For thorium the best guess is 1,000,000 tons. Here we define recoverable as that which is obtainable at about $100 a pound or less for metal in billets. Assuming that each fission of a single nucleus—U–233, U–235, or Pu–239—yields 200 MEV of energy and that a practical conversion or breeding ratio of 1 to 1 is obtainable, so that U–238, which comprises the bulk of natural uranium, and Th–232 can be tranmuted to Pu–239 and U–233 respectively as fast as fissionable material is consumed, the total energy is uranium is approximately 17×10^{20} B. t. u. and the total energy in thorium is approximately 71×10^{18} B. t. u. The grand total, then, for nuclear fuels is almost 18×10^{20} B. t. u. This is 220 times the energy residual in the oil and natural gas reserves.

The figure of main interest to us, however, is the reserve energy ratio between nuclear fuels and the lumped sum of conventional fuels. All together

coal and oil and natural gas represent about 80 x 10^{15} B. t. u. Therefore, there is about 23 times as much energy residual in the world's nuclear fuel reserves as there is in the world's "fossil fuel" reserves. This bare fact is one of the strongest arguments in favor of the development of a nuclear power industry.

CONSUMPTION OF CONVENTIONAL FUELS

The question still remains—How fast are we consuming our "fossil fuels"? How soon will we be forced to turn to nuclear fuels for power?

Dr. Fieldner has calculated that allowing for a 50-percent loss of energy in conversion of coal to fuel oil and other liquid hydrocarbons which will be required by our economy after natural sources of oil have been depleted, all coal will be consumed in 654 years. This is predicated on a continuance of the present rate of fossil-fuel consumption. In the interest of accurate prediction, however, two modifying factors must be taken into account: (1) The expanding world population, and (2) the increasing demand per person for power.

The present population of the world is approximately 2.3 billion. At the current rate of growth (9 per 1,000 per year) this population will double itself in 85 years. To be conservative, let us assume that it will double itself in a century.

The Edison Electric Institute tells us that power consumption per capita in the United States has doubled in the last 10 years. On the basis of this, it is probably safe to assume that power consumption per capita for the world will double each 50 years during the next century.

Combining these factors one sees that in all probability world consumption of power will be 8 times what it is today in 100 years, 64 times what it is today in 200 years. It takes only a little computation from these figures to estimate that our coal (comprising the bulk of our fossil fuels) will last not 654 years, but about 100 years.

One hundred years is not a long time—particularly since as the specialized uses for coal and oil grow (anad they surely will), we will undoubtedly want to conserve both materials as much as possible. Of course, 100 years may not be correct; it may be 50 years or it may be 200 years. Estimates of reserves will certainly change and actual consumption will vary from that assumed. But it certainly is wise for us to think ahead as best we can with the best information available, and plan accordingly. To me this means that we had better start pushing nuclear power now. Reactor engineering is a complex technology and cannot be mastered in a decade. Later, I shall try to point out why.

ECONOMICS OF NUCLEAR POWER PLANTS

I said that I would also try to prove that there may be an economic advantage to nuclear power. The corollary to this is that nuclear power may be desirable at even an earlier date than indicated by the above. My reasoning here is probably too simplified, but it goes like this: As more and more of our oil and coal is used up, costs of production will rise because poorer and poorer sources will have to be exploited. This I maintain despite the fact that improved extraction methods will work in the opposite direction. With the fuel costs, power costs will rise. But even on the basis of present-day costs, the fuel costs of nuclear power plants are negligible. One pound of uranium, if completely "burned," will produce about 10 million kilowatt-hours of heat. This equals 3.5 x 10^{10} B. t. u., or, in terms of coal, slightly less than 2.7 x 10^{6} pounds (1,300 tons). In terms of cents per kilowatt hours of electricity this is 0.0039, as compared with 0.43 for coal on today's market.

Naturally a nuclear power plant is going to cost more than a conventional power plant. A reactor is a much more complex device than the steam boiler which it replaces. Also, special facilities must be provided to fabricate the nuclear fuel into rods or other suitable shapes and to reprocess to recover both unused and bred (spelled b-r-e-d) fuel after irradiation. But the savings effected by the low cost of raw fuel give promise of more than offsetting the increased investment required.

How much more we can afford to pay each year through fuel savings to amortize a reactor rather than a conventional boiler may be estimated as follows: Postulate a reactor operating at a 500-milliwatt heat-output level and with an on-stream factor of 300 days each year. Three hundred days equals seven thousand, two hundred hours. The total heat output in a year, then, is $7{,}200 \times 500 = 3{,}600{,}000$ milliwatt-hours or 3.6×10^{9} kilowatt-hours. Coal to pro-

duce this amount of heat would cost about $4,000,000. Taking fabrication and chemical processing costs into consideration, uranium to produce this amount of heat would cost no more than $100,000. The difference—$3,900,000—can be applied to write-off of the excess construction costs of the reactor. On a conservative basis this permits approximately $20,000,000 more to be spent on the nuclear end of a power plant than on a conventional boiler. Is this enough, in the present state of the art? This I cannot answer—but you see that we have room to play.

REACTOR FUNDAMENTALS

Now—what are these animals called reactors to which I have been referring so blithely? To understand the principles of construction and operation of a nuclear reactor one must have a rudimentary knowledge of neutron physics and the fission process. This you undoubtedly have, but just to refresh your minds on the subject, let me review a few of the essentials.

Most of you are electrical engineers. You are in the business of pushing electrons around. Don't look open-mouthed at physicists. The particles you work with weigh only one one thousand, eight hundred and fortieth as much as the particles we work with. On the other hand, ours is a sneakier particle in that it has no charge and despite its mass is no bigger than yours. For this reason it is harder to control. But also for this reason it is essential to the fission chain reaction (see p. 3)—which makes the nuclear reactor tick.

Being neutral and immune to so-called Coulomb forces, the neutron can cross the high-potential barriers surrounding a nucleus at will. It can enter and break up a nucleus as no other particle can. When it enters a U–235 or a Pu–239 nucleus, for example, it creates such a disturbance that the invaded body flies into two major pieces and several minor ones (2 or 3 other neutrons) with explosive violence. This is known as fission. If there is a sufficient number of other U–235 or Pu–239 nuclei in the vicinity to catch one of the emitted neutrons before it undergoes some extraneous process, such as radiative capture, the fission process is continued indefinitely. A "fission chain reaction" is the result.

On top of this, if one or more of the extra neutrons are captured by U–238 or some other "fertile" material, a transmutation to more fissionable material (Pu–239 in the case of U–238) may occur and the result is "breeding"—the production of as much or more fissionable material than is consumed.

This last may sound like perpetual motion—and it is, in a way—but theoretically it is entirely possible. A special reactor to test its practicability is now in operation at the National Reactor Test Station in Idaho.

REACTOR DESIGN AND OPERATION

Some reactors utilize the nascent (energetic) neutrons emitted by their fissioning nuclei immediately. These are called "fast" reactors. Other reactors, called "thermal" reactors, slow the neutrons down before allowing them to be reabsorbed by fissionable material. The latter require a goodly amount of so-called moderating material interspersed between the fuel elements.

A "moderator," or "moderating material" is one which will slow the neutron down rapidly (that is, remove its energy in big chunks by collision) without absorbing it parasitically. The lighter nuclei are the best moderators because they approach the mass of the neutron. The hydrogen nucleus is almost exactly the same weight as the neutron, in fact. The principle is that of the collision between two balls. If they are of approximately the same weight, the momentum of a ball in motion can be imparted entirely or almost entirely to one at rest. You have seen this on the billiard table many times. On the other hand, a ping-pong ball would not impart much of its energy to a billiard ball no matter how hard you impelled it. It would merely bounce back almost as fast as it was sent forward.

But, as I have emphasized, size isn't the only criterion for a "moderator." It must not absorb the neutron parasitically; it must keep it bouncing. This prolongs the life of the neutron and gives it a chance to eventually find its way back to a U–235 or Pu–239 nucleus.

A reactor operates successfully, of course, only when the neutrons produced by fission minus those lost in the moderator, the coolant, the shield and the structural material and those absorbed by control rods are equal to or greater than the number of fissions.

A great deal of heat is given off by the process of fission. Otherwise we would not be gathered here tonight. This results from the conversion of a small amount of mass into energy according to Einstein's law: $E=mc^2$. In other words, the total mass of the fission fragments plus the neutrons does not equal the total mass of the original nucleus plus the invading neutron. The difference is minute, but because C, the speed of light, is so large (3×10^{10} cms./sec.) only a very small mass is required to produce a tremendous amount of energy.

Most of this energy (162 out of 195 MEV) is confined to the heavy fission fragments in the form of kinetic energy (heat), but much of the rest of the energy (that of the neutrons, the gamma rays, the beta particles, etc.) is finally reduced to heat, too. Enough of this, however. I have already cited the vast quantities of heat which may be drawn from "burning" a pound of natural uranium (1 part U–235 to 140 parts U–238).

The reason I bring up heat in connection with the design of the nuclear reactor is because it must be removed or the temperature of the reactor may rise to dangerous heights. This requires, in ordinary designs, a labyrinth of cooling tubes. These must be threaded carefully through the latticework of fuel and moderator to insure both maximum neutron economy and maximum cooling effect, two objects which often oppose one another. For each reactor design a different optimum arrangement must be worked out—on top of the myriad possibilities with regard to fuel and moderator arrangement. Of course, both the coolant and the pipes must be non-neutron-absorbing.

Another complication is that adequate control of the neutron population throughout the reactor must be provided. Otherwise, the chain reaction might proceed at an explosive rate. This control is usually achieved with rods of boron or cadmium or some other neutron-sink material which are fitted to shafts built into the pile (another term for reactor) and are provided with fast-acting and dependable actuating mechanisms to insure that they are continuously adjusted to compensate for fluctuations in the pile activity.

The end result is a pretty complex array of equipment—especially after one adds in such things as "scram" devices, "test" holes, measuring instruments, and so on.

I hope you now have some idea of how a nuclear reactor works. When you see one (and I trust they will be open to the public someday) you will probably see only a tremendous concrete block through which all sorts of tubes, shafts, pipelines, wires, and sundry conduits are threaded, each with its own port or valve. Around the outside of this monolithic structure will be an ordered array of complicated electronic equipment, test instruments, control-rod actuators, coolant pumps, and signals.

Why can't you look inside? Why is all that concrete around it? That comprises the shield. Internally a reactor is a veritable cauldron of neutron bullets and "hot" gamma rays. Both neutron and gamma radiations are lethal if received in sufficient dosage. The effect is cumulative over short periods. But the level of radioactivity around the outside of a reactor must be kept sufficiently low so that operators and maintenance personnel can be continuously on duty. This means that a sufficient mass of dense material must be built around the reactor to absorb the neutrons escaping the lattice and to attenuate the gamma rays. Furthermore, each tube or wire running into the interior must be bent or baffled and properly gasketed. Neutrons seem to have a predilection for cracks.

PROBLEMS OF REACTOR DESIGN

You are now aware that developing and designing nuclear reactors is no easy task. If you'll allow me to recapitulate, the major problems are these:

(1) To develop coolants and materials of construction with low "absorption cross section"—that is, substances which do not absorb neutrons parasitically.

(2) To develop coolants and materials of construction capable of withstanding intense and prolonged neutron bombardment without suffering deleterious changes.

(3) To develop coolants and materials of construction capable of withstanding high temperatures.

(4) To prove out the "breeding" process.

(5) To reduce or eliminate the need for expensive fuel-element fabrication.

(6) To reduce the complexity of chemical reprocessing to recover both unused and "bred" fuel.

(7) To develop noncorrosive coolants and liquid fuels and moderators.

(8) To develop durable containers and conduits for these coolants and other liquids.

(9) To design reactors with higher specific heat outputs, thus reducing both size and cost (these presumably will be "fast" reactors).

(10) To develop adequate control devices for "fast" reactors.

(11) To achieve high "burn-up" so that the need for chemical reprocessing of fuel is reduced.

(12) To fabricate the required intricate shield shapes economically and with minimum volume.

(13) To design more efficient heat-transfer equipment.

(14) To develop methods of handling and disposing radioactive wastes which will minimize health hazards.

INDUSTRIAL PARTICIPATION PROGRAM

These problems are being tackled on many fronts both inside and outside the AEC. The Commission, of course, has a planned program of research and development which it is hoped will eventually lead to efficient power-producing reactors. It is not depending on its own brains and resources alone, however. It realizes that the major portion of the engineering know-how of the Nation is to be found in private industry. Consequently, about 16 months ago an "industrial participation program" was launched. Industrial and utility firms were invited to engage in preliminary studies of the practicability of privately financed development, construction, and operation of reactors for the production of fissionable materials and power.

The companies who replied to this call in time to be admitted to the first round of studies were Dow Chemical and Detroit Edison, Monsanto Chemical and Union Electric, Bechtel Corp. and Pacific Gas and Electric, and Commonwealth Edison and Public Service Co. of Northern Illinois. All four of these groups have completed a comprehensive survey of the reactor field and have written reports covering their findings and recommendations. These reports are currently being evaluated by the Commission staff, although the proposal of one group—Dow Chemical and Detroit Edison—has been accepted and negotiations are in progress leading toward a contract to cover an advanced developmental phase of the program.

As you undoubtedly know, a second invitation to engage in nuclear-power feasibility studies was released to the press in April of this year. Since then six additional firms or groups of firms have been heard from, and just last week the acceptance of one of these proposals was announced. This was submitted by the Pioneer Service & Engineering Co. of Chicago and the Foster Wheeler Corp. of New York.

Through the medium of these continuing close contacts with private enterprise the Atomic Energy Commission hopes not only to add to the talent and technical ability of its own staff but also to gain an insight into the over-all power picture which it is felt is unobtainable from within a Government organization. In other words, the Commission is inviting competition in the nuclear-power field. It is encouraging business and industry to help carry the load. As a Government agency it will continue to insure the provision of fundamental knowledge necessary to permit the full-blown operation of the private enterprise system but, as Commissioner Glennan has said, it will not attempt to direct the future course of this vast new industry unless private enterprise fails to take up the challenge.

As I see it, the AEC will, of course, continue to cooperate with the Department of Defense in the design and manufacture of bigger and better nuclear weapons. In a parallel vein, it will continue to carry on an extensive program of development of reactors which are particularly suitable for military use—for example, the submarine reactors now under construction and the aircraft reactors now under development. The initiative for development of central station power reactors may be partially transferred to private industry, however.

REACTORS BUILT OR BEING BUILT

The "first wave" of reactors in the AEC's reactor development program has finally landed on the beach and we are reaping some of the benefits which they were planned to provide.

The materials testing reactor, which was recently put in operation at the National Reactor Test Station in Idaho, is supplying us already with new information on the effects of continuous and heavy neutron bombardment on the physical

properties of various structural materials—materials which will be utilized in later reactor designs to improve performance, if they are found suitable.

I have mentioned the experimental breeder reactor at the same site. This is proving invaluable in our study of the feasibility of breeding and, as an added dividend, has been utilized to make steam sufficient to operate a 100 kw. electric power plant—the first instance of the harnessing of nuclear power. The Argonne National Laboratory near Chicago designed and is operating this reactor.

The third reactor in the "first wave" is the submarine thermal reactor. This is the product of a joint effort by Argonne National Laboratory and the Westinghouse Electric Corp. It is now under construction at NRTS.

Another submarine propulsion unit, the submarine intermediate reactor, is presently being designed and developed by the Knolls Atomic Power Laboratory, which is operated for the AEC by the General Electric Co. Construction of a land-based prototype has begun at West Milton, N. Y., near Schenectady. This project differs from the submarine thermal reactor in that the neutrons are moderated only to intermediate energies, not to thermal energies, and in that a liquid metal coolant will be employed. This completes the "first wave" of reactors.

In the "second wave" of reactors—those which are presently being planned—many of the problems that I have mentioned will be tackled and solved. Some information on one of these advanced reactors has already been released to the public. I refer to the homogeneous reactor which has been developed at the Oak Ridge National Laboratory. The reactors I have mentioned previously are all classified as heterogeneous. This means that the fuel elements, the moderator elements, and the coolant tubes for these units were fabricated separately and arranged in a predetermined geometric pattern. I need not repeat that this is an expensive procedure. The homogeneous type of reactor gives some promise of eliminating this expense. This type consists principally of a soup or slurry or solution in which the fuel compounds and the moderator material are mixed in liquid form. Cooling is accomplished by circulating the mixture or solution through an external heat exchanger. You can readily see that such a development, if successful, would help to solve problems 5, 6, and 13 above, but would probably complicate problems 7, 8, and 9.

Work on reactors for the propulsion of aircraft and for powering a large surface ship may be said to belong to this "second wave," and I anticipate that development of central-station nuclear power plants will follow.

How much progress we have made in the solution of our problems I am not permitted to say. Security regulations in this regard are strict. I believe I can predict with some degree of certainly, however, that appreciable blocks of commercial electric power will be supplied by nuclear power plants within the next decade. First usage will probably occur in areas where conventional power is expensive. Let me emphasize that these are purely personal predictions, however.

There is no doubt in my mind that nuclear power plants are technically feasible today. Our major objective now is to improve technology and reduce costs enough to permit competition with established power plants. When we recall that the neutron was discovered only 20 years ago, that 13 years ago we were just learning of the process of fission itself and the possibility of initiating a chain reaction, that intensive work on nuclear energy was started only 11 years ago, that the first nuclear reactor was triggered only 10 years ago, and that—following the magnificent achievements of the Manhattan Engineering District during World War II—the Atomic Energy Commission has been in business only 5 years, we realize how fast we are progressing and we gain confidence in the future I have predicted.

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106. OUR ELECTRICAL FUTURE

By G. M. Gadsby

(General Electric Forum, Hotel Utah, Salt Lake City, November 14, 1952)

A day such as you have spent working through the industrial forum called to consider Modern Electrical Methods for Industry, has left you saturated with timely technical information to the point that you have no room for further absorption. As the concluding number on this program, dealing with our electrical future, I shall not attempt the impossible by offering you more technical material.

The program notes dealing with the various speakers and subjects have been well prepared by those responsible for setting up this forum. The optimistic and imaginative suggestions which are ascribed to my talk I willingly accept.

Many years ago I recall hearing a speaker at one of our conventions say that the record of the electric-utility industry was that of a race in which the regulators were continuously stepping on the heels of the engineers and technicians, the implication being that the progress of the electrical art was exceedingly rapid with the fruits of efficiency, and increased production promptly plucked by the regulatory authorities. I did not then accept, nor has my experience since established the truth of this statement. I can go along on the theme of great technical advancement, and with the implied thought that the advantages of these advances have been passed along to the users of our service. Most of this, however, has been a voluntary action prompted by a concept of good business.

A review of the electric industry since its birth in Pearl Street is one of which we are all proud, both as to the achievements on the part of the manufacturers and the promotion and sales efforts on the part of the operating utility companies. We passed through a great era of expansion in which the holding company played an important and constructive part. In times still vivid in my own memory I know of the difficulties encountered in securing the finances necessary to keep the industry abreast the inventive genius and brilliant sales promotions of all branches of our industry from the manufacturer to the local contractor.

The cumulative results covered by this fine history up to 1946 have been dwarfed by the tremendous expansion of the past 6 years. The 50,000,000 kilowatts of installed generating capacity then the total of both investor-owned and Government plants increased 50 percent in 5 years to a total of 75,500,000 kilowatts at the end of 1951. Giving effect to the increased population, the per capita use of electricity in the same period increased 47 percent. Upon no less an authority than our mutual friend, Chet Lang, the average use of electricity in our industrial plants in 1951 was 7 kilowatt-hours per man hour, with the ratio increasing month by month as additional generating capacity is added to the supply. It is difficult to visualize the dramatic significance of these few statistics. They indicate that built into our tools of production is now power of such magnitude that each average worker has under his direction the equivalent of 154 men. Nor is the picture complete unless we recognize the great versatility of these hidden crews. In numbers they are not equally distributed, in some instances the hidden crew will reach a thousand or more directed by one human being, in others the hidden power is of almost microscopic dimensions but of unbelievable skill and adaptability.

General statistics are available only to the end of 1951. Going back to that date and taking a future look, the plans for expansion are even greater. Before the enlarged requirements for atomic energy projects which have developed this year, definite plans were made and in large part covered by firm orders for adding another 30,000,000 kilowatts of capacity during the 3 years 1952 through 1954, further growth of about 40 percent, not on the 1946 base, but on the total capability at the end of 1951. With additional requirements of the Atomic Energy Commission, DEPA had added at least 2,000,000 more kilowatts to this schedule bringing the total planned capability at the end of 1954 up to the tremendously high level of 110,000,000 kilowatts. While a large part of this new capacity is going into operations other than mechanical power, nonetheless, the growth so far outstrips the increase in the working force that it requires no mathematics to project the increase in hidden manpower to a gang of 250 unseen workers for each visible individual on the production line.

Turning to our 8-State Rocky Mountain region, data gathered in the last few months show the investor-owned companies during the 6 years to the end of 1951 increased their generating capacity by about 1,000,000 kilowatts which is more than 75 percent of their total installed capacity at the end of 1945. Over 700,000 more kilowatts have "come on the line" this year, are under construction or are projected on definite plans for the 3 years 1952 through 1954.

In this 9-year period from 1946 to 1954 these investor-owned companies will have spent approximately three-quarters of a billion dollars on new electric service facilities of all types.

A portent of the future is to be found in the joint undertakings of investor-owned companies uniting to build projects of such magnitude as many of our people have believed to be possible only by the Federal Government. The 5-company Electric Energy, Inc., building the great plant at Joppa to supply half of

the energy requirements of the Atomic Energy Commission plant at Paducah, Ky., and the 15-company combination Ohio Valley Electric Co. just formed to build two power plants on the Ohio River at an aggregate cost of some $450 million to supply the 1,800,000 kilowatts required for the AEC plant in Pike County, Ohio, are illustrative of this vision, courage, and capability of investor ownership.

No look at the future would be complete without reference to potential, and perhaps quite near, developments in the use of atomic energy or some of its corollary forms of energy as a fuel source for thermal electric generating plants. Experimental work is now actively under way, and a goodly number of our electric operating companies are combining with other industrial concerns to push research in this field. Just recently Mr. Philip Sporn, president of the American Gas & Electric Co., who is one of the best-posted utility men in this field, stated, "There is no doubt of the technical feasibility of producing fuel for electric power from nuclear energy, but the prospect of cheap power from this source is still only a hope."

One road block to the advance of peacetime uses of nuclear energy is the restrictive features of the present Atomic Energy Act. This law was enacted in a time of stress and at the very beginning of the burgeoning atomic age. Some of its provisions would lead one to think it was written by men who believe in the socialistic principle that the state should control the means of production. Now that the people of the country have so clearly expressed their aversion to socialistic trends, we have reason to hope that a different approach to commercial development in the atomic-energy field will be encouraged, and the basic law amended so that, commensurate with national safety, this incalculable source of future energy will be open to incentive development and productive uses for peaceful industrial purposes under our American enterprise system.

The Utah Power & Light Co. has been very glad to join in the sponsorship of this forum. In our own local experience we profited by the technical improvements in thermal plants. Incorporated in the second unit of the local Gadsby plant is the reheat feature which will give a marked improvement in efficiency and capability over the No. 1 unit, although both are of the same name-plate rated capacity. During the 3 years ended 1951, our company and its subsidiary, the Western Colorado Power Co., actually spent over $40 million for new facilities, and in the 3 years ending 1954 will add $40 to $45 million more for additional generating capacity, transmission lines, and other equipment fully to meet the needs of our expanding service area.

We hope you have enjoyed and profited by your day's discussions, and that we may again have the opportunity of being cosponsors for a like informative meeting.

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107. AEC REPORT ON POWER STUDY BY ARMY

UNITED STATES ATOMIC ENERGY COMMISSION,
Washington, D. C., November 21, 1952.

Mr. WILLIAM L. BORDEN,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. BORDEN: In reply to your letter of November 14, 1952, I am glad to give you a brief report concerning studies by the Army Corps of Engineers of possible applications of atomic energy for electric power generation.

The Secretary of the Army recently requested the Commission to cooperate in a study seeking to determine the exact nature of requirements that might be filled by power from atomic-energy sources as well as the reactor designs most suitable for this purpose. He pointed out the Army's feeling that in time the advantages of a power source free from conventional fuel requirements may justify the costs involved.

In his reply, Mr. Dean advised the Secretary of the Commission's desire to cooperate in this study. He suggested in view of the Commission's prior studies in this field that the Army obtain all available information prior to embarking on a program and pointed out the desirability of any contracts involving study or development of new reactor designs being handled by the Commission. He also suggested that when the Army has completed development of the scope of its interest in the field of reactors, the Commission's Reactor Development Division will be available to evaluate the possibility of meeting any Army needs

from available reactor designs and also the necessity of any new design contracts.

In furtherance of this exchange, Col. James B. Lampert, of the Army Corps of Engineers, has reported to the Commission in a liaison capacity with the Division of Reactor Development. Currently, he is working with our staff to develop in a preliminary fashion the more likely reactor possibilities which might be adapted or developed for Army use. At the same time he is carrying forward within the Army a detailed study of the Army's power requirements and the military considerations affecting possible utilization of reactors for power generation by the Army.

We expect in the reasonably near future to arrive at some preliminary conclusions in this joint investigation which should indicate the feasibility and possible scope of a more definitive research and development program.

If we can supply any further information I would be glad to do so.

Sincerely yours,

M. W. BOYER,
General Manager.

108. CHICAGO CONFERENCE ON ATOMIC POWER

Tape recording of Chicago University Conference, commemorating the tenth anniversary of the operation of the first nuclear pile, University of Chicago, Chicago, Ill., December 2, 1952.

Participants:

Dr. Enrico Fermi, Nobel Prize Winner in Physics.
Dr. Arthur Compton, Chancelor, Washington University, St. Louis, Mo.
Dr. Walter Zinn, Director, Argonne National Laboratory.
Dr. Charles A. Thomas, President, Monsanto Chemical Co.
Mr. Murray Joslin, President, Commonwealth Edison Co.
Mr. Crawford H. Greenewalt, President, the du Pont Co.
Prof. W. Allen Wallis, School of Business and Chairman Committee on Statistics, University of Chicago.
Dr. Donald Loughridge, Assistant Director, Division of Reactor Development, Atomic Energy Commission.

Dr. ARTHUR COMPTON. In choosing a chairman for our panel today, we turn to a young man who is an old friend of the university. We knew him as a man who both individually and as a representative of his company has given devoted service to his country. During the dark days of the war, he spent much time with the scientists who worked in the laboratories under the west stand on our campus. His task was to bring the great scientific and organizational strength of his company to bear on one of our Nation's most urgent problems, the construction of a vastly complex and totally new industry, the large-scale production of plutonium.

Without a background of scientific research and particularly fundamental research and a tradition of flexible and farseeing management, he and his associates would never have been able to begin the job; and, perhaps, it would not be inappropriate to remind the Government of our country at this time that without bigness, the company, as we came to call it, could never have successfully discharged the gigantic task assigned it.

And at a profit, may I remind everyone, of exactly $1. Gentlemen it is a pleasure to introduce you to the president of one of America's great industrial pioneers, the du Pont Co., Mr. Crawford H. Greenewalt.

The CHAIRMAN. (Mr. Greenewalt). Ladies and gentlemen, it seems quite appropriate on this day which is the tenth anniversary of the first self-sustaining chain reaction, to consider what the future holds for that new source of energy. That is a very difficult problem because, actually, I don't think there is much before us that we can say that is a reality. So that I think the answer to that question will require the use of several crystal balls. Now, I notice that the gentlemen on the panel don't have their crystal balls with them—perhaps they have them in their pocket. I might say, also, that I can think of no more distinguished panel to deal with this subject—and I should think that if anybody can deal with it, the gentlemen that you see before you can deal with it as well as anyone could.

We are to discuss the industrial uses of atomic energy in the next 10 years. I agree fully with what Dr. Compton said to you a few moments ago about the current use of atomic energy. It is unfortunate that it should have to be used for the defense of the Nation, but there it is and that is something I don't suppose we can avoid. I think, however, that the constructive thing is to look

farther ahead to the time when—God willing—it will not have to be used for the defense of the Nation and that great source of energy can be turned to the advancement of the world in peace.

Now, without further ado, I think I should now introduce to you your very distinguished and knowledgeable panel. I am glad I don't have to compete with them. All I have to do is to keep them in order, which I also hope will not be necessary.

We have, as representing the Atomic Energy Commission, Dr. William Davidson, who is Director of the Office of Industrial Development and is taking the place of Mr. Gordon Dean.

We have, also, of the Atomic Energy Commission, Dr. Donald Loughridge, an Assistant Director of Reactor Development, who is taking the place of Dr. Hafstad.

We have Dr. Arthur Compton who has already distinguished himself before you, who is chancelor, as you know, of Washington University; Dr. Enrico Fermi of the Charles Swift distinguished service professor of physicists and of the Institute for Nuclear Studies.

Mr. Murray Joslin, assistant to the president of the Commonwealth Edison Co., brings to us the point of view of one of the great public utilities.

Dr. Charles Allen Thomas, president of the Monsanto Chemical Co. Dr. Thomas, himself and his company, have contributed enormously to the development of atomic energy so far.

Dr. Wallis, professor of the school of business and chairman of the committee of statistics of the University of Chicago, and Dr. Walter Zinn, Director of the Argonne Laboratory of the United States Atomic Energy Commission.

So, you see, gentlemen, we have business, science, government, and with that combination, I am quite confident that any problem, no matter how complex, can be well and promptly dealt with.

Now, there has been a great deal of talk earlier today about reactors or, as they are sometimes called, piles; and I am wondering if it would not add, perhaps, to the understanding of you ladies and gentlemen, if we had a brief discussion of a pile, or an atomic reactor, so that you would understand what it is and in simple language how it works. I would like, if I may, to ask Dr. Fermi if he would not explain that to you, using the model which you will see at his left.

Dr. FERMI. You see here a scale model of the first atomic pile. Let me first mention to you that this white part is merely a wooden scaffolding that serves as a support for a good part of the rest of the structure, and the most visible thing that has a functional significance is this black material. It is bricks of graphite, very many of them piled up in this pile which was, I think, a little bit over 20 feet high. So that gives you approximately the dimensions.

But, of course, it is not only graphite inside, there is uranium spread throughout the interior of this mass. Very many of these bricks of graphite were approximately this long, this wide, this high, would contain holes drilled into them in which some amount of uranium or of uranium oxide was lodged. And now, I will tell you briefly that this machine would start to work by itself the moment the last layer of graphite is added if all those things here which simulate control rods were removed from it. And it would start to operate as follows:

There would be some neutrons produced in the uranium that would collide against the graphite, be slowed down to the appropriate energy, react again with uranium; produce more neutrons and then again slow down, react, and so on and so forth at a rate that would be controlled. If the structure is too small, too many of these neutrons would fly away. But as soon as the mass becomes large enough—and actually the thing of which this is modeled was barely large enough—there would be always a small excess so that the reaction would gather momentum as it goes and at a rather leisurely pace increase in its intensity.

At the rate at which this unit was operated 10 years ago, you hardly would see anything unless you were equipped with suitable instruments, but if you had been so reckless as to let the thing go on unchecked—let's say overnight—well, or maybe for a few hours, then the rate of reaction would have been so great that this mass could conceivably have become red hot and would have killed everybody in sight by the intensity of its radiation.

Now, this of course would have been very unpleasant for us, for 41 people were about the room at the time so we thought it would be a good idea to control the reaction. This is done by means of only one of these many control rods, which have essentially the following function:

As you see, they can be inserted deeper inside or further out of the mass and what they do is essentially to eat up some of the neutrons that keep the reaction

going. If you want the reaction to proceed faster, you remove some of these cadmium rods. If you want to proceed slower, you push it in, and controlling this huge mass of material is usually done by a reasonably skillful operator—skillful, not necessarily very skillful operation, merely by watching an instrument that indicates the level of reaction and moving this thing in and out as the case demands.

This, I think, is the general idea which you had in mind.

The CHAIRMAN. It is indeed.

Now, ladies, with that introduction, perhaps we can come to our knitting. I think I should also tell you that this discussion that follows is practically unrehearsed. We had a little get-together this morning, but the argument went so hot and heavy I was unable to get through the outline, so perhaps some of that argument will translate itself usefully in the discussion we are going to have now.

I would like to open the discussion by posing this question for our panel:

What industrial applications for atomic energy can now be foreseen? and in asking them to answer that question, I would like for the time being to take off the 10-year limitation that has been imposed on the title. So that I would like to have the answer to that question without the 10-year time axis so that we can see at the moment what gleams in the eye for industrial application are before us. I think since the Atomic Energy Commission has been dealing most importantly with that question, I would like to ask Dr. Davidson if he wouldn't lead off.

Dr. DAVIDSON. Before I do attempt to answer that, I would like to express the sincere regrets of Mr. Dean that he is unable to be here today. He had looked forward to attending this meeting, but as often happens, an unexpected problem arose at the last moment, and he had to bow out.

Now, after the succinct address by Dr. Compton and the demonstration by Dr. Fermi, it is, perhaps, a bit anticlimatical for me to attempt to tell you what uses we might expect from nuclear energy in the future. But very briefly, we might review that by just asking ourselves what are the products of nuclear fission? They are really three in number. First, tremendous amounts of heat: two, extra neutrons which can be utilized to make more fissionable material, or to make radioactive isotopes; and, three, great fluxes of nuclear radiation seething within the reactor and also much radiation coming from the ashes of the fission process, namely, the fission product produced at some later time. So those are the three things we have to work with. Radioisotopes which are made in the reactor in great quantities due to its adoption of neutrons which are already being used rather extensively in industrial work both at the research development and process control level. We know more today about what makes alloys strong, how sulfur vulcanizes rubber and how some of the worth-while chemical reactions take place, thanks to the use of radioisotopes. We also can use them in thickness gages to precisely measure the thickness of layers of paper and rubber. One of these thickness gages potentially can save a rubber or paper manufacturer literally thousands of dollars annually even though it only contains a few dollars' worth of a radioisotope.

We have not yet found commercially worth-while uses for these nuclear radiations which are available to us in tremendous quantities. However, a couple of years ago, the Stanford Research Institute was commissioned by the Commission to look into the possible use of these things and they came up with a number of potentially valuable uses. These include the sterilization of high-cost materials such as antibiotics and hormones, things that can't be sterilized with heat, because they break down in the process. Even the sterilization of food, if these fission products can be packaged and made available on an economic basis, perhaps used to activate low-level light sources and static eliminators and perhaps even as a low-level, low-demand power source. So, you see, potentially there are a considerable number of industrial uses for these radiations. And the third product is the one that makes the nuclear reactor engineers' eyes glisten, namely, these tremendous quantities of heat which can be obtained from the nuclear fission process. And, of course, we think, there, in terms of power and processed heat for industry and conceivably, sometime in the future, for using nuclear power in propelling commercial vehicles both on the sea and in the air as well as the military is now thinking of doing this with their military vehicles. This very briefly, I think, puts in some perspective the outlook for the products of the fission process today.

The CHAIRMAN. Are there any other ideas as to potential industrial applications? Dr. Thomas, do you want to put on your rose-tinted glasses?

Dr. THOMAS. Not just yet.

The CHAIRMAN. Dr. Fermi, have you any suggestion as to where these results might be used industrially?

Dr. FERMI. Not really; I think his enumeration was quite complete. Of course, I always think in good part of the use for science, which indirectly will bear on industrial results, and there are, of course, a number of things that can be done in that line.

The CHAIRMAN. Dr. Compton, do you wish to add anything?

Dr. COMPTON. I think I have already given some comments on the general field which have been similar to those of Mr. Davidson, but I would emphasize likewise, with Fermi, the importance in the scientific field which, as one looks down the line, has great possibilities before it.

I think of the use particularly of the tracer chemical, tracer isotopes.

There is also the field in the more specifically scientific aspects in the use of the neutrons as alternates to other kinds of radiation with which one can do things, and these, although not of direct industrial importance, our experience shows us that whenever you find something that is important scientifically, before long it becomes likewise significant in the industrial way. These are things, I think, however, as you suggest, that go beyond our 10-year limit.

The CHAIRMAN. Then I wonder if it isn't fair to summarize the answer to the question in this way: That we have already developed a number of uses for these radioactive isotopes.

We have some further possible applications for the radiations that emanate from the pile or from the isotopes themselves. We have a vast number of possibilities as aids to science, let us say, secondary to other investigations.

Then we have finally the very large question of power and power generation.

Now, to put these things in proper perspective, I think I would like to come to the next question, and that is: Do any members of the panel think that the uses for the isotope, the radiation, sterilization of food, or any of the other things not connected with power generation, could be sufficiently important to justify in their own right an atomic reactor development program? Dr. Thomas, can I get you on that one?

Dr. THOMAS. I feel that the great use in my lifetime, or maybe my son's lifetime, or children's lifetime—and I am particularly interested in that, really, is in power. And outside of that I don't see that there is very much to talk about. As a scientific tool; yes. As radioisotopes as a tool, certainly I wouldn't minimize that. But from an industrial standpoint to bring something to the world, I think power overshadows everything that we see in the next 10 years. That is my own personal feeling.

The CHAIRMAN. Perhaps in that connection I might try to develop another point. I understand that the Atomic Energy Commission is operating at Oak Ridge a reactor whose principal application is the supply of these radioactive isotopes as they are used in science today.

I understand also that the arrangement that the Atomic Energy Commission makes is to sell those isotopes at cost. And I suppose that that implies a rather substantial governmental subsidy in their production.

Is that right Dr. Davidson?

Dr. DAVIDSON. That is essentially right. The Government only attempts to collect the out-of-pocket cost in the production of these isotopes, though, assuming that the reactor was already built and would be used for Commission work anyhow; so it is not necessary to ask the public or the users of these isotopes to pay the overhead and the amortization costs on reactors.

The CHAIRMAN. I suppose then it would be fair to say that if the Atomic Energy Commission charged full cost for the isotopes that it makes at Clinton, in other words, if it attempted to make the Clinton reactor a profitable matter, as we normally consider private enterprise profit, the price of these isotopes would be out of reach.

Dr. DAVIDSON. I think you are probably right. It is true that two commercial organizations, namely, the Bendix people and the Tracer Lab people, are currently looking into this possibility.

Now they haven't rendered their final reports, but I think you are probably safe in saying that it doesn't look that they could compete very favorably with the present prices of radioisotopes as charged by the Government.

The CHAIRMAN. Then would the panel agree with this summing up: That unless there is an industrially profitable production of power, these secondary uses will be so expensive that they will have to be subsidized in one form or another?

Dr. DAVIDSON. I would put it this way: That dollarwise, certainly, power is the big product we have to worry about or consider in the future.

The CHAIRMAN. Well, I think we have, perhaps, narrowed the topic for discussion down to the power question, which is certainly the large one. We can agree that these uses, attractive and important though they may be from a commercial sense, will be byproduct uses and will come into their own perhaps after a power development has been successfully made.

Dr. COMPTON. One comment before we make that too firm. Mr. Davidson called attention to the fact that one of the products is neutrons and that these neutrons can be used for producing isotopes.

I would merely call attention to the fact that the most important of those isotopes commercially now is plutonium, and that has a very great importance. It has a great importance for the national safety at the present time, and one does not see clearly down the line, but that it may have continuing importance. If we include the value of the plutonium, I would say that we might even reverse our idea as to where the industrial significance comes. If we put a price on the plutonium. But I think that has already been discounted from the way you approached the problem. I am merely pointing out it is really the value as a source of neutrons to produce isotopes that is the prime reason for existence at the present time.

The CHAIRMAN. I wonder if we could make that point crystal clear, Dr. Compton. I was eliminating in these questions I have been asking the military uses of either plutonium or U–235 entirely.

I was assuming that in God's good time there will be no need for stockpiling these things as instruments of war. Assuming that time has come, do you still feel that the applications of plutonium for peacetime purposes are sufficiently important to make that an end in itself, something that is worth while from a commercial point of view?

Dr. COMPTON. If you put it for the next 10 years, I would say "No." But if you put it for a period down the line further, I would strongly suspect that plutonium might be found to be an exceedingly important article of commerce as a concentrated source of readily available energy.

The CHAIRMAN. But there again it is because of its energy content and not because of any inherent chemical nature of plutonium itself that you think it would be valuable?

Dr. COMPTON. I would agree.

The CHAIRMAN. So that in a sense, really, we come back to the power question. Well, now that certainly is the $64 question.

There has been a great deal that has been written about atomic power, much of it, I must say, in my view at least—perhaps I should not have a view as moderator—but overoptimistic. I wonder whether since we are now going to embark into the power question, it wouldn't be worth while to ask Mr. Joslin as representative of one of our great public utilities, who makes his living on the production and sale of power, to tell us a little something about the present situation economically; in other words, what competition atomic energy must meet if it is to take its place as a prime resource of power.

Would you be prepared to discuss that for a few minutes, Mr. Joslin?

Mr. JOSLIN. I might first say, Mr. Greenewalt, I am like the sand-lot baseball player who suddenly finds himself playing on the New York Yankees.

My group, the group that is studying power, is a group of Commonwealth Edison & Public Service Co. of Northern Illinois engineers, and at the end of our first year of studies we found, or concluded, that electricity from the nuclear power plant that we know how to build today will cost more than that produced by a conventional power station fueled with coal, oil, or gas.

On the other hand, we qualified this otherwise disappointing conclusion by stating that, one, nuclear power is feasible. In fact, we submitted two feasible designs. Feasible meaning practical from an engineering, construction and operating standpoint but not necessarily economic.

And, second, we feel that at least one of the designs could be economic, and there are, no doubt a number of others if credited, with the present military value of the plutonium produced.

This is where we get right to the heart of the plutonium question.

Or, putting it another way around: A dual purpose, that is, a power and plutonium reactor, can probably reduce the cost of plutonium for the military through the credit received from the power produced.

Now if these statements have any validity, you might ask: Well why isn't the problem solved? And why don't we start construction? But there are two serious drawbacks, as I see it.

First, no one knows how long the military market for plutonium will be sustained, and we feel that the value of plutonium as a fuel is considerably less than its value as weapons material.

Nuclear power plant investment costs, incidentally, are high, and therefore this long-term market is needed to allow for reasonable amortization.

Secondly, military decisions determine the expansion of plutonium production facilities. Time schedules for completion are all-important. The stakes are apparently too high to accept the later completion date of a somewhat more complicated dual-purpose plant, or incur that remote risk of failure. It's obvious that there is less risk in building more of the same kind of reactors we now have, and it can be done quicker.

We, therefore, are in no position to be critical of this status of nuclear power that you hear bandied around so much these days. I think there is more criticism without your group of experts in the field than from outside. And that's a valid one, that's one where the team that won the tough series has got a right to do a little Monday-morning quarterbacking about how much better they might have played the game.

But the thing that we are rather concerned about and want to be rather serious about, is that in this next decade, or two decades, for that matter, where we go on this matter of nuclear power is going to depend an awful lot on the decisions made today, and the most needed decision is to build a nuclear power plant in order to get the actual operating experience.

The utility industry, with which I am more familiar, did not spend years of research and development so that its first electric generating station might employ high pressure, high-temperature equipment, and high-capacity circuit breakers. The historic Pearl Street Station of Edison was not even a model T, it was a one-lunger. And even though we are amateurs in the field, relatively, we think we could build a model T nuclear power plant today. However, we are so impressed with this collective ability and ingenuity and knowledge that has accumulated in the field that we feel we are on the verge of economic nuclear power, if you please; we are on the verge, but a lot depends on whether or not we make a start.

The CHAIRMAN. Now, if I could sum up your point of view, Mr. Joslin, I take it it is something like this: That you would regard it as entirely feasible to build a model T, as you call it, plant that would generate electricity and at the same time would make plutonium.

Your point about economics is that unless the Government is willing to pay a weapons price for the plutonium that that plant produces, such a development could not be economic. Is that correct?

Mr. JOSLIN. That is correct.

The CHAIRMAN. I wonder what the Atomic Energy Commission has to say on that subject.

Mr. LOUGHRIDGE. I wonder if you would speak to that.

Mr. LOUGHRIDGE. Thank you, Mr. Greenewalt. I would like to comment on that, because in general I certainly agree with Mr. Joslin in what he has said, and I would like to introduce one additional idea, however, though, that I think the American public has not quite realized in the past—how much contribution military support has been in a number of our at present everyday types of technical items.

For instance, take the airplane. It is my belief that without, call it heavy subsidization, if you want, or probably what many people would choose to call it, large purchases of airplanes, I do not believe that we would have the commercial aviation which you have at the present time. A large amount of the development of our modern type commercial airplane arose from research and development funds . . .

(End of first tape.)

The CHAIRMAN. Well, I take it that we are all agreed, at least I hope we are, on this premise that power from atomic energy entirely for itself is not economic in the light of today's knowledge; that, however, Mr. Joslin and Mr. Loughridge both appear to believe—Mr. Loughridge that the development, Mr. Joslin that

a dual-purpose plant which makes plutonium along with power, would help the development of the power, per se, alone, by virtue of what is learned in connection with the construction of those plants.

That, I take it, is the point of view with which you both would agree.

We have had nothing but sweetness and light so far. Is there anyone who disagrees with that point of view?

Dr. FERMI. There is one point on which I merely seek information. Power, I suppose, has a different cost in different locations. Near the coal mine the power is cheaper, and when we are at a place where hydroelectric power can be developed it is cheap. There are places, perhaps not so much in this country as through the world, where conditions may not be so favorable.

I wonder whether anybody has the elements to discuss this point of view. I would personally be interested to know whether the argument that power cannot compete without price of the plutonium produced potentially as a weapon would apply geographically to all the world or to most of the world, or to the United States, or to where.

The CHAIRMAN. Well, is there anyone wishes to deal with that question? Is there any knowledge on that question?

Dr. Davidson, have your people given consideration to that problem?

Dr. DAVIDSON. Why, the Commission has given quite a bit of consideration to that, and in fact today has a team looking into the high cost areas in this country.

This team is a part of the Reactor Development Division, so I think Dr. Loughridge can probably tell us what the status, if it is available for publication at the moment.

Dr. LOUGHRIDGE. It is in the study status, so the final conclusions aren't available yet, but I can say this:

In the preliminary survey we find that the cost of power fluctuates tremendously around the country by factors of four, five, six or more. And it is fair to say, I think, at the present time that the Army is becoming greatly interested in the possibility of the type, what you might call, package power reactor, which could be placed in very isolated communities where there is no hope of any other type of power, but for military reasons they would like to have power there; and the cost, of course, would be prohibitive from the standpoint of the commercial power.

But from those standpoints, to try to answer Dr. Fermi's question, I think we can say the cost of power within the continental limits of the United States varies all over the map. You can get about anything you want to, although it is nothing in comparison to what the Army would be prepared to pay for it in such outlying places as northern Alaska.

The CHAIRMAN. Then I take it, Dr. Loughridge, the answer to Dr. Fermi's question, in your view, would be that looking at power generation from a strictly commercial and nonmilitary point of view, you do not know of any location in this country at least where it would be conceivable that power from atomic energy would be commercially fruitful.

Dr. LOUGHRIDGE. I wouldn't want to make that categorical answer right now, No. I think Dr. Zinn has some ideas on this.

The CHAIRMAN. I would like to hear from him.

Dr. ZINN. I would like to remark that we started out by saying that research uses, and so on, did not provide any considerable market for atomic power.

If you talk about places where power is exceedingly expensive, there can't be a very large market. So how can you interest utilities and so on in the problem?

Utility companies in this country will necessarily be interested in large markets. This means competing with an industry which has had many years of development and has done very wonderful things in making electricity out of coal.

This is the basic problem and leads to what I call the power dilemma.

We know now how to make nuclear machines which will generate power at cost which is, let us say, an order of magnitude greater than what is now used, or the cost in commercial establishments.

A submarine reactor is being built. This would have a cost of an order of magnitude or more.

We also know how to run very large reactor plants for making plutonium. The problem is to bring these together and get the power out of a large machine at a competitive cost, and the dilemma arises because if we try to make the plant small, the cost turns out to be large; if we make the plant very large, where we have some chance of getting the cost, let us say, within a factor of two of

competitive price, then the capital investment is very large; and the question is, Whose money shall it be? This is the basic dilemma.

The CHAIRMAN. I think that is a very fair statement of the problem.

Now I wonder, then, if we could get down—and now I think we are getting into the realm of sheer speculation—I wonder whether we could get down to what I would like to call the atomic energy power problem, per se; and that is that the problems we face in designing and building a power plant whose prime product will be power, and which does not have to rely upon the sale or other disposition of any byproducts.

Now, in opening that question, I would like again, I think, to call on Mr. Joslin and Dr. Loughridge to see if we can get some numbers here that indicate how far away, in some quantitative way, we are from the goal.

As I understand, Mr. Joslin, it is the point of view of the utilities that the atomic-energy installation would replace merely the boiler and the steam that is generated; that is, the electrical-generating equipment, and all of that would have to be the same, whether one generated power from atomic energy or from coal. Now, I wonder if you could give us a figure on, let's say, the cost per installed kilowatt, of that part of a coal station which would be replaced by an atomic-energy unit.

Mr. JOSLIN. Yes. The present-day costs run a little different in different parts of the country, but we could assume $170 to $200 per kilowatt of installed generating capacity for the total plant, including the fuel handling and carrying it through to stepping up the electrical output, and putting it on a transmission grid.

Of that, possibly $80 to $100 would be associated with the boilers and coal handling that would be displaced by the reactor.

Now, there is another factor in here which we had quite a debate about in some of our preliminaries this morning: What would be the capitalized value of the fuel? And it is quite a debatable point. But you have got to assume that you are burning something else of just zero fuel costs, namely, the uranium for the moment, displacing the coal. And figures will vary all over the map because of the wide range of fuel costs in different parts of the country, but we might say $100 to $200 is the capitalized value of the fuel; and add the $100, the lower figure, to the $80 representing the investment in the portion of the plant displaced by the reactor, and you get $180, or you get a range of $180 to $300 per kilowatt for comparison of the nuclear substitute investment.

Is that what you wanted?

The CHAIRMAN. That is what I wanted.

I would like to know, also, whether anybody would quarrel with those figures, substantially.

Dr. ZINN. Only in one sense. Let's not get the idea that the fuel cost for a nuclear plant would necessarily be zero. It would be far from zero. It depends on what kind of plants you build; how you run it.

The CHAIRMAN. We will come to that.

Then we can say the goal we are shooting for, in other words, what competition, let's say, has to offer atomic energy is something that is worth $180, let's say, per installed kilowatt.

Now, Dr. Loughridge, I wonder if you could give us a figure that would represent your best present ideas on costs for an atomic energy plant per installed kilowatt.

Dr. LOUGHRIDGE. One figure which has been released, I believe, during the last few months, is the estimated cost per kilowatt for power generators in the case of our first nuclear submarine installation. It turns out to be in the order of magnitude of $1,400 per kilowatt in comparison to $180 that has just been quoted. However, I would like to point out that is rather unfair comparison due to the fact that that figure includes a rather very expensive naval plumbing to withstand shock, and one thing or another, and seems to me not to be a fair figure to use for comparisons.

Another figure I have picked up from the Navy is the total cost of the fuel and loading and transportation, all the logistics involved in this to operate a submarine, runs in the order of $1.50 per kilowatt. So you see the power cost there is terrific.

I think a fair comparison would be, if we want to get some figure to compare with this $180 figure per kilowatt, which Mr. Joslin has mentioned, would be probably somewhere in the order of five to six hundred dollars per kilowatt with our present technique.

I think we can't compete yet.

The CHAIRMAN. Well, there we are now. We have a figure of $180 per kilowatt for a present modern coal installation, and we have a figure, which I suppose

at best is a very high-spot guess, of five to six hundred dollars for an atomic energy installation that could be made today.

So you can see at a glance that the gap is a rather wide one.

Now I think it is time to deal with another $64 question, and that is the assumption that the cost of the fuel in an atomic energy installation is zero.

I think I know what Dr. Zinn has in mind in questioning that that may be so, and that I think brings in this question of breeding. Is that right, Wally?

Now this question of breeder—I suppose you have seen that in the newspapers, and I am not sure that I know full well what it implies, and since Dr. Fermi did such an excellent job in explaining the pile to you, I wonder if I could prevail upon his good nature to tell you something about breeding and what it means in terms of this problem of power generation.

Dr. FERMI. Uranium, as you know, contains two components, of which one is active in the normal sense, and that is the so-called uranium 235 present in the amount of about seven parts in thousand. The remaining 993 parts in thousand are uranium 238, which is normally inactive.

Now, from a long-range point of view of a power industry based on uranium, clearly, it is irritating if we should take the point of view that we can use only this seven-tenths of a percent of active component.

Now at least theoretically—how much practically, other people in this group are much better qualified to say—but at least theoretically this does not have to be an assumption because of the following circumstances:

You know in the Hanford reactor plutonium is fabricated, which is a substance very similar in its general property to the active component of uranium, uranium 235.

Now, this substance, plutonium, is produced by converting into it the inactive part of the uranium, the uranium 238. And by and large, in the Hanford reactors, this plutonium is fabricated at the expense of the uranium 235 to active component.

Now, the question arises, What is the total balance of this in this process? Do we produce more plutonium than we destroy uranium 235, or is it the opposite? Because in the former case we have a possibility of keeping on and on. First we take uranium that has this seven-tenths of a percent of the active component we use to fabricate, shall we say, for example, eight-tenths percent of plutonium. Then we take this 8 percent, and we fabricate perhaps 9 percent, and so on. We can go on in principle along this line until we have consumed practically all of the bulk of the uranium of the 993 parts per thousand.

This is the essential idea of breeding. And I may say that theoretically it is almost sure that breeding is a possibility, but the fact that it is a theoretical possibility leaves me still quite open-minded as to the question whether it is also a practical possibility.

The CHAIRMAN. Then, could we put it this way—that the assumption that the fuel will cost a negligible amount in an atomic energy plant is dependent upon our ability to design a reactor that will breed. Because obviously, if one can only use seven parts per thousand of the charged material, the fuel cost can scarcely be negligible and may be very substantial.

So that the assumption that the fuel will cost nothing is dependent upon the solution of the breeding problem.

Now I know Dr. Zinn has been very much interested in solving the breeding unit, and I would like him to speak for a moment, if he will, upon the feasibility of designing a unit that will breed in fact.

Dr. ZINN. I would like to first say it is not necessary to carry the process to the extent that was indicated by Dr. Fermi.

It should be realized that if you burn up 100 atoms of uranium 235 and replace it, let us say, by 80 atoms of plutonium, and then burn those 80 atoms of plutonium and replace those by some other plutonium atoms, and so on, you have expended very considerably the 0.7 percent of uranium 235 available.

This regeneration of fuel and burning it in the reactor is the thing that gives us the possibility of getting the fuel costs low. Now, we call it breeding when it actually turns out to produce more atoms of the plutonium than atoms of uranium 235 burned. But this is just an imaginary boundary line and is not necessarily the crucial point.

I believe that reactors which can do this, namely, replace some of the uranium 235 by plutonium, and then burn the plutonium, are practical today, and that such reactors are the ones that ought to be built as the first ones in an attempt to make economical central-station power.

If we don't take this line—but rather say that we will put off attempting to get some regeneration—then we will not ultimately have much chance of competing with coal as a fuel for power plant.

Mr. THOMAS. May I take an exception to that? I've been waiting for this.

The CHAIRMAN. I was hoping we would get a little controversy.

Mr. THOMAS. I have no control with Wally Zinn or anybody else on breeders, on any of this thing. I think it is splendid. But I do not have to call to your attention, Mr. Greenewalt, this word "monopoly," I am sure.

Some of us are fearful of monopoly in Government as we are in other places. And the paradoxical thing is that the Atomic Energy Commission is just as afraid of it and would like to break this monopoly in the future.

Now, the way to stop a monopoly and the way to get started on this thing is to get moving. I think Wally Zinn's idea, I would certainly underline it. But I think the way to start—as my good friend Mr. Joslin has said—is to start out with the model T Ford, because I think many plants will have to be built before we get to the ultimate.

Therefore, I have advocated 2 years ago this dual-purpose plant. It seems to me strange to worry about the usefulness of plutonium when the Atomic Energy Commission hasn't broken ground on additional plants to produce more plutonium. Therefore, I would think that a combination plant, whereby making plutonium, selling it to the Government, at a price no more than it is costing the Government using the same bookkeeping methods in both processes, over a period of 5 to 7 years, wouldn't be a sound way to get started to make power economically, which we feel we can do at present times carrying a dual-purpose plant.

Now, as Dr. Zinn points out, quite correctly, this is largely a plutonium plant. So what? We certainly need plutonium or you wouldn't be building more additional plutonium plants today. But by making this combination in the interim period in the next 10 years to get started, to throw this thing open to industry, we feel is important.

I think the fact that there is disagreement between Dr. Zinn and myself is a great compliment to the fact that he believes in competition. If anybody wished to have a plant going one way, and we wished to have a plant going the other way, we think it is in practice with the American industry to let them go their respective ways and not have a governing body set up who is going to appoint additional committees to study this plan and that plan, and then pass judgment on which one is correct. Let's throw it open, and if we fall on our face, let us fall on our face; if Dr. Zinn falls on his face, let him fall on his face. But just get this thing open to competition.

The CHAIRMAN. Well, there we are, gentlemen, completely unrehearsed. I take it, however, Dr. Thomas, that you would still feel that this so-called dual-purpose plant is no more than a step, but in your view a very necessary step on the way to what I have called an atomic power plant, per se.

Mr. THOMAS. That is correct, but I think it is an essential step, because it is time to get started on this thing, and I think probably after we got this plant built that we would have something that was obsolete.

Well, Dr. Greenewalt and I both know in the chemical industry this is usually the case. We build plants that are practically not finished before they are obsolete, and that is something we have to contend with.

Now, Dr. Zinn, what are you going to say?

Dr. ZINN. Well, just this: I have seen two plants in their design and construction phase, whose purpose it is to make plutonium, and I think I know a great deal about how they were designed and how they are to be operated.

I have also seen an experimental plant which makes electricity in its design stage and operation, and I have had close connection with a plant which will operate submarine; so I think I know something about a plant which will make power.

I am getting a little impatient, however, in looking at plants which always make something else. They make plutonium or they make military power, but they are not directed toward making civilian power and making it economically. I am fearful that as long as we keep our eyes on making something else, the thing we really want won't come about. And there is a real danger here, because the things that are something else have a very high price, and this very high price does not encourage in the designers and the builders and the operators the greatest care in getting the capital costs down, the capital costs of the plant, and it is this high capital cost which leads to the five or six hundred dollar figure that Dr. Loughridge mentioned.

I have, of course, every hope that competition would do this, but we need to have more than one such plant under construction, and not a guaranteed price of plutonium from the Government, but a competitive price of plutonium for the military use, in order to get the costs down. The guaranteed price from the Government can hardly be called competition, because you are competing with plants which were built under entirely different arrangements, not to get the cost of power down.

Dr. THOMAS. Dr. Zinn, as this is unrehearsed, let it be unrehearsed. There is a counterproposal, which I think you endorsed, where the Government subsidizes power, that is, this package power plant; and Dr. Fermi spoke of places where the small power plant would be possible and you fell right back into the argument the military would need it.

Now in this dual-purpose plant, unless the plutonium could stand on its own feet competitive with what the Government could make plutonium for, it would not have my endorsement.

Now there is such a thing as amortization, and the thing I am speaking of is that if the high capital costs of a nuclear reactor, a dual-purpose plant, selling plutonium competitive at the present costs of the Government, it gives you an opportunity over 5 years to write that capital off. Then you have an entirely different picture, and then you have your capital costs reduced, because any of us who have fooled with this—and I am not doubting your great knowledge in it, I assure you—realize that the capital costs are the biggest cost items in the cost of atomic power plants.

Dr. ZINN. Then, isn't the difficulty that perhaps the only plutonium plant the Government really has now under your basis of 5 years is already amortized? It is rather tough to compete with it.

Dr. THOMAS. I don't think so, because you are building some more at Savannah River. Dr. Loughridge can tell us more of that, if he can. I don't know; it may be classified.

It is not the power plants that you have at Washington that were built in wartime we are speaking of; we are talking about the plutonium plants not in production yet which are now under construction.

Dr. WALLIS. I would like to ask Dr. Zinn what he would think of simply having the Government call for competitive bids for supplying plutonium.

Dr. ZINN. I don't think you would get any bids.

Dr. THOMAS. Dr. Z nn, that is where I differ with you.

Dr. WALLIS. Doesn't that view bring out one of the difficulties of having any real competition here? And this is the point: I think there is a real difference between atomic-energy subsidy through the purchase of plutonium and the subsidy of the aircraft industry and Diesel-engine industry that Mr. Loughridge referred to. In those cases, the airplane industry, the Government has subsidized most indirectly. What they have done is not tell people how to build airplanes and to monopolize all the technical knowledge under security wraps on how to build airplanes.

Instead, they have largely subsidized it simply by contracting for air-mail service. They didn't even tell the airlines what kind of airplanes they had to buy.

In this business that seems to be not practical because of the security problem. I wonder whether, as long as the security situation is what it has to be, there is any real hope for competition.

The essential social advantage of competition comes through the possibility of free entry of anyone—fly-by-night operators—people that the Government doesn't have to investigate either for loyalty or for financial soundness. That is the check we have on big firms. It seems to me it is completely out of the picture as far as I make it out in the atomic-energy business within the visible future.

The CHAIRMAN. Well, let's see where we are now.

Dr. THOMAS. I didn't quite understand that, Dr. Wallis. What is completely out of the picture?

Dr. WALLACE. To release the technical knowledge that would be necessary for independent operators to decide on their own whether they would like to go into this business and whether it can be done better than it is being done now, whether there are resources available that could be devoted to that industry that are not being devoted now, and, in general, to fall on their faces freely, as you put it.

Dr. THOMAS. I really believe Dr. Warren Johnson if he were up here could speak to that, but he is on this committee of declassification, and I think with the Commission's help—and they have been very helpful in this—you are going

to find more declassification, not of a military nature but of nuclear reactors. At least, I hope there will be in the future.

Dr. WALLACE. On this declassification, I wonder, I might say doubt, that they have economists, for example, studying this declassification problem. They probably have chemists, physicists, and military experts. One of the big issues involved would be what would be the economic gains, what would be the effect on the general social organization of our productive structure, of releasing this to free competition, letting the knowledge become available—what would be the gains there as against the obvious losses from releasing the information.

If you take the airplane as an example, I think offhand that if the Wright brothers had just built their airplane, everybody would say the Government has got to get that completely under wraps, it is a menacing weapon, as it is. But I wonder whether the United States would have the preeminent position in aircraft production that it has if we had handled it the way we are handling atomic energy; whether the risks that we took in letting the knowledge become available to other countries—indeed we even sold the first of some of the important models of airplanes to foreign countries—I wonder whether those gains don't tend to be overlooked in the declassification procedures.

Dr. LOUGHRIDGE. I think that is an interesting point, Mr. Greenewalt, that Mr. Wallace has made. I would like to ask the industries that have been involved in this during the last year or so, whether the fact that although Commission, of course, has not opened up perfectly free to anybody to get in and read all the information that is available on this field; as far as these particular selected 10 companies is concerned, that has been the case. So it seems to me that this security thing is overworked in many cases, because certainly my impression is that it does not interfere with your personnel's operations at all. Is that not true?

Dr. THOMAS. I agree with you fully.

Dr. WALLIS. I am worried about the companies that are not in the picture now, though, that were unknown companies the way the big aircraft companies were 40 years ago.

Dr. THOMAS. I imagine there must have been people worried about that when Fulton first had his steamboat. But there you are: The Atomic Energy Commission has been very fine in inviting these groups in, and I think you know they have 10 in—because they didn't come in, I don't think you want to force them—but there are 10 companies which have had this information available.

The CHAIRMAN. I think probably that is enough for that phase of it, because I gather really there is no essential conflict between the points of view that have been expressed as to the ultimate goals.

I think everybody agrees that we are not yet able to build a competitive power plant, per se, and the argument that has taken place so eloquently by these various proponents . . .

(End of second tape.)

Dr. LOUGHRIDGE. The Commission asked Putnam to look into this very matter, and he concluded if you do admit the possibility of using all the economically recoverable uranium, that there is several times as much heat energy in the uranium that can be economically mined as there is in the coal that can be economically mined from the earth. On that basis, I think we can conclude that we do have sufficient nuclear fuels available if we can only find an economic way to get them.

The CHAIRMAN. Ladies and gentlemen, I would like to close by asking a real question. I think we have developed today there is still a substantial difference of opinion when we can have an economic competitive atomic energy power generating unit.

You have heard considerable discussion about various methods of arriving at that goal. I would like the panel really to look into their crystal balls and say when that goal will be reached, whether it will be 10 years, 20 years, 50 years, or never.

Let's go around the table. Dr. Loughridge?

Dr. LOUGHRIDGE. I will forecast 15 years.

The CHAIRMAN. Fifteen years before we have an economic unit.

Dr. Davidson?

Dr. DAVIDSON. I have always noted when we are asking this question and hearing it be kicked around, that the optimists are those people who have never built a reactor. I have never built a reactor, so I will say within 10 years I think we will be able to demonstrate that power can be made competitive from nuclear fuel.

The CHAIRMAN. Professor Wallace?

Professor WALLACE. I have absolutely no technical competence in the field, so before the meeting I looked up the history on similar predictions on other in-

ventions that have been made in the past, and my prediction is that none of the predictions made here or elsewhere will bear any relation at all to what actually happens.

The CHAIRMAN. I think that is probably the wisest answer of all.

Dr. Fermi?

Dr. FERMI. Subject to full agreement with Mr. Wallace's conclusion, my impression is that 20 years may be a reasonable figure.

The CHAIRMAN. Dr. Compton?

Dr. COMPTON. I already gave earlier some crystal-ball gazing, and I think I would stay by it. I would be surprised if we do not have some actual commercial applications of atomic power within 10 years.

Those will be in the more expensive power areas. In large scale production of power, on an economic basis, my guess would be closer to 50 years.

The CHAIRMAN. Dr. Zinn?

Dr. ZINN. It depends a good deal on when you set your mind to do it. You haven't heard here today anything about the infeasibility of doing it. You haven't had any hint that we need some new technical approach in order to make it possible. Therefore, what is needed is decision and determination to give it a whirl. And I believe that it may take 3 or 4 or 5 years to make up our minds to build a large-scale plant specifically for making power. When we do this, after another 3 or 4 years for construction, we will have it.

The CHAIRMAN. That adds up to 10 years approximately.

Mr. Joslin?

Mr. JOSLIN. Again the sand lotter. It can be, I believe, within 10 years, talking economic power again; but it is not likely to be at the rate it is moving.

The CHAIRMAN. Dr. Thomas?

Dr. THOMAS. I find myself in just complete agreement with Dr. Zinn, what he just said. And I would rather not comment on this question, but I think it is completely irrelevant. I think this question has been posed at every panel that we have ever had on this subject, and I think it completely ought to be outlawed.

What is important is to first get the law changed. You cannot have any commercial power with the existing law, as it now exists, in my opinion. It doesn't have to be changed radically, but there has to be some changes in detail on the law. And I think I agree so fully with Dr. Zinn and with Dr. Wallace that the important thing is to get moving and get started and not worry about when we are going to do it because that is the question that I think is so burning before the American public and the world today. So I have no comment to predict when it will be. I am only urging that we get started.

The CHAIRMAN. Now you have all the answers.

(After closing remarks of thanks, adjournment.)

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